1969
SOIL PLANT NUTRIENT RESEARCH REPORT

compiled by

J.L. HENRY

E.H. HALSTEAD

Department of Soil Science

University of Saskatchewan

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In soil fertility research, it is vital to conduct experiments under a wide variety of soil conditions and climatic factors. Almost all of the investigations were carried out on individual farms throughout the province. Without the generous co-operation of the many farmers involved, it would be impossible to conduct research of this type and this co-operation is gratefully acknowledged.

The work on the nutrient requirements of irrigated crops was conducted at the site of the South Saskatchewan River Irrigation Project. The co-operation and assistance of Messrs. A.D. Hutcheon, G. Hart, V. Davies, and A. Bristol of the Conservation and Development Branch, Saskatchewan Department of Agriculture, and Mr. L. Sonmor of the Canada Department of Agriculture was much appreciated.

The major responsibility for the field work connected with the School of Agriculture trials was carried by Mr. G. Herndier. Mr. E. DeYong accepted similar responsibility for the potassium and sulfur experiments. Messrs. J. Sadler and J. Bettany were responsible for work involving radioactive tracers. Other assistants who aided in various projects were D. McKenzie, L. Rygh, G. McLean, D. Ehman, B. Whaley and K. Wilson.

The 1969 work comprises the final year of a five-year program designed to evaluate the fertilizer requirements of stubble-seeded crops. The financial assistance provided during this period by agencies other than those previously listed is also acknowledged. The V.L.A. Co-operative project was a vital segment of the overall program and provided an extensive coverage of the province at a minimum cost. Thanks are extended to all V.L.A. credit advisors and farmers who have assisted with this program.

Highlights of the 1969 Soil Fertility Research Program

1. The final year of the five-year stubble fertilizer research report confirmed earlier results supporting the nitrate test as a valuable tool in predicting the nitrogen requirements of stubble seeded crops. A composite report will summarize the results of all data obtained over the course of the project.
2. A single experiment on a Grey Wooded soil to study the efficiency of sources and placement of nitrogen indicated similar results for seed placed and broadcast treatments with urea and ammonium nitrate. It should be noted that this work represents only one set of soil and climatic conditions. Further work is required in this area on a wide range of soil conditions.
3. The 1969 data confirmed earlier conclusions that ammonium polyphosphate (15-60-0) is a suitable source of phosphorus for cereal grains in Saskatchewan. Some inconsistency in uptake patterns of ammonium polyphosphate (15-60-0) and monoammonium phosphate (11-48-0) was found with rapeseed. Further investigations may be required in this area on a wider range of crops.
4. The yields of barley are severely limited by potassium deficiencies on soils which have low potassium soil test levels. As indicated in earlier reports, the yields of wheat are not affected by potassium deficiencies to the same extent. An extension of the program of 1969 to areas of higher soil test levels indicated that the current soil test benchmarks for potassium are reasonably sound. Further tests are required for barley to determine if this crop will respond to potash fertilization in the medium range of soil test levels.

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1.1.1 School of Agriculture Trials

PURPOSE

To evaluate and refine the current soil test benchmarks for nitrogen applied on stubble-seeded crops.

EXPERIMENTAL METHODS

Seventeen strip trials were laid down on stubble land and the majority of these were on farms of former students of the School of Agriculture. The test crops grown were wheat (9 sites), barley (6 sites), and oats (2 sites).

A standard plot design was used at all of the sites. Phosphorus in the form of monoammonium phosphate (11-48-0) was applied with the seed at 30 lb P_2O_5/acre. Ammonium nitrate (34-0-0) was broadcast in strips at rates to supply 20, 30, 40, 60 and 80 lb/acre of nitrogen, in addition to the nitrogen in the 11-48-0. The nitrogen was broadcast, prior to seeding, with a six-foot truck-mounted Cominco 70 fertilizer attachment. All other operations were done with the farmers' equipment. Each of the strips was 12 feet wide and ½ mile, or less, in length.

Composite soil samples, from the width of the plot, were taken at each of the ten sampling sites (replicates). The sampling sites were selected on the basis of slope position to obtain sites representative of the plot area. The three standard depths (0-6", 6-12" and 12-24") were used.

Three-square-yard samples of the grain were cut for each of the treatments at the ten sampling sites (replicates). Two of the barley plots (Hult at Waseca and Greer at Sovereign) were completely hailed out. Therefore, yield data was obtained on only 15 of the 17 tests.

RESULTS

The yield results (Table 1) show consistent high responses to broadcast nitrogen for soils testing in the very low range. Responses were only slightly lower in the low nitrogen soil test range. Responses to nitrogen also were obtained in the medium, high and very high soil test ranges. However, extreme variability in the response pattern was evident in these higher soil test ranges.

The variability in the response patterns was particularly evident with barley and oats as the test crop. The wide fluctuations with the barley on the Estevan soil (Good plot) was not totally unexpected. Solonetz and solodized solonetz profiles occurred in the plot area. As is typical of complexes of these two profiles, the area is characterized by extreme variability in crop growth. It appears that special techniques are required to obtain reliable fertilizer response data on highly complex soil associations within the Solonetzic Order.

The data from the 1969 nitrogen-stubble tests (School of Agriculture) represents the final year in the five-year stubble fertilizer project. A complete analysis of the five-year project is being carried out. When this analysis is complete, it will be possible to refine, if necessary, the current soil test benchmarks for nitrogen fertilization in Saskatchewan.

Table 1. Yield response to nitrogen fertilization of crops seeded on stubble land.

Farmer	Crop	Soil Type	Soil NO_3-N lb/acre 0-24"	11-48-0 @60 yield bu/acre	Yield increase to additional nitrogen at 20 lb/acre	30	40	60	80
				Very Low Nitrogen Tests					
Ayres	Wheat	Br:l	18	18.9	9.5	11.1	11.5	14.0	9.0
Hamilton	Wheat	W:l	16	17.9	8.6	9.5	7.4	12.6	14.2
Kowalenko	Wheat	E:sicl	17	21.6	4.5	7.9	7.6	7.7	11.7
Latrace	Barley	E:sicl	20	25.6	10.1	14.5	13.4	12.9	20.2
				Low Nitrogen Tests					
Coolidge	Wheat	Wa:l	30	24.7	8.8	1.8	8.7	4.6	9.0
Herndier	Wheat	I:c	32	18.9	7.7	8.7	7.5	10.1	12.5
Raven	Wheat	Wv:l	28	18.1	2.1	6.9	11.3	11.7	14.0
Wallace	Wheat	W:l	33	18.4	1.4	6.1	-2.3	4.1	8.3
Turvey	Barley	Wa:cl	22	35.6	18.6	5.6	15.8	10.3	23.5
				Medium Nitrogen Tests					
Longmire	Wheat	R:hvc-Sc:hvc	36	25.4	7.5	7.0	7.8	5.7	7.0
B. Bruce	Oats	R:hvc	41	61.4	15.5	14.8	25.0	7.1	23.3
				High, Very High and Very High+ Nitrogen Tests					
Froh	Barley	T:cl	53	51.5	9.4	7.4	11.3	6.1	12.6
Good	Barley	Es:l	79	49.6	12.9	1.6	20.4	-2.0	10.8
Wallin	Wheat	Y:l	62	33.9	5.3	3.6	0.4	4.3	8.1
R. Bruce	Oats	R:hvc	55	61.8	-6.1	6.3	16.5	5.0	4.3

1.1.2 <u>V.L.A. co-operative tests</u>

The V.L.A. co-operative stubble fertilizer project provides extensive information on fertilizer response throughout the entire province. In addition, information is obtained on the performance of soil test recommendations in comparison with the general recommendations. Twenty-two strip tests were seeded in which the following treatments were compared:

(i) check

(ii) 11-48-0 @ 40 lb/acre

(iii) 23-23-0 @ 87 lb/acre

(iv) 11-48-0 @ 40 lb/acre, plus 33.5-0-0 @ 100 lb/acre

(v) soil test recommendation if it differed significantly from any of the above treatments.

All seeding and fertilizing operations were conducted with the farmers' equipment under the supervision of the V.L.A. credit advisors. Soil samples were taken in the fall of 1968 and again in the spring of 1969. The soil test recommendation was based on the fall soil test. All of the plots were harvested and yield data obtained. Two of the plots were combine harvested and the remainder were harvested by the square-yard technique.

The comparison of the fall and spring sampling (Table 2) indicates serious discrepancies between the two sampling dates for some of the sites. Of the 19 plots for which the comparison can be made, a difference in the recommendation of greater than 10 lb N/acre would have occurred at 7 of the sites. Similar comparisons in 1968 (see 1968 Soil-Plant Nutrient Research Report) showed

Table 2. Comparison of fall and spring soil test data for V.L.A. co-operative tests.

Advisor	Farmer	Nitrate Nitrogen lb/acre 0-24" Fall/68	Nitrate Nitrogen lb/acre 0-24" Spr./69	Available P lb/acre 0-6" Fall/68	Available P lb/acre 0-6" Spr./69	Available K lb/acre 0-6" Fall/68	Available K lb/acre 0-6" Spring/69
Baker	Hayward	22	-	23	-	672	-
Cox	Ford	23	39	16	26	456	504
Draftenza	Denis	38	29	34	37	900+	900+
Kendel	Tosh	16	46	22	30	588	368
King	Craig	19	21	18	36	620	604
Laing	Boechler	6	51	24	35	128	96
McDonald	Yakubowich	39	53	17	20	268	200
Mackay	Stadnick	20	79	22	35	652	812
McLeod	Beddome	33	40	12	11	712	496
Murch	Adair	17	24	23	15	900+	528
Peace	Porter	14	45	47	48	792	744
Puckey	Nowosad	24	30	22	20	900+	696
Salkeld	Keith	37	104	35	34	900+	704
Sherwin	Selvig	15	45	19	24	560	544
Sikora	Kulovany	29	74	25	25	288	276
Simpson	Zunti	23	33	20	32	744	824
Steabner	Peckham	41	47	30	24	744	560
Steenson	Frolek	24	21	12	13	320	257
Stewart	McLeod	-	30	-	24	-	624
Welwood	Lindstrom	-	83	-	20	-	228
White	Hooper	9	20	20	23	328	308
Zinkhan	Currie	6	34	42	38	864	840

differences in recommended rate of nitrogen of greater than 10 lb per acre in only six of 22 sites. The results (Table 2) show reasonable agreement for phosphorus and potassium, but serious discrepancies in nitrogen occurred at some sites. In the past, the discrepancies in fall and spring samplings have been attributed to sampling error. The fact that spring values are almost invariably higher than fall values indicates that sampling errors or inadequacies are not the only cause of variation. The data suggests that more basic research should be conducted to elucidate the factors responsible for the apparent increase in nitrate nitrogen from fall to spring. Such information would allow more accurate evaluation of the nitrogen fertility status and would further increase the effectiveness of the nitrate test in predicting nitrogen fertilizer requirements.

As the V.L.A. tests are located at widely scattered sites throughout the entire province, the data are useful in determining fertilizer effects on a broad provincial basis. The average data (Table 3) show excellent responses in most cases. Contrary to the results of other years (Figure 1), the split application (11-48-0 + 33.5-0-0) did not yield higher than the seed-placed 23-23-0, when wheat was used as the test crop. The data shows a slight increase in yields (both check and fertilized) in going from 1967 to 1968 and from 1968 to 1969. With barley as the test crop, the split application was definitely superior to the 23-23-0 treatment.

Table 3. Average check yields and yield increases for V,L.A. co-operative tests

Crop	Check Yield (bu/acre)	Yield Increase to 11-48-0 @ 40**	23-23-0 @ 85	11-48-0 @ 40 + 33.5-0-0 @ 100
Wheat (12)*	19.8	3.0	6.5	5.3
Barley (5)	26.9	6.2	5.5	13.6
Durum (1)	30.2	3.5	16.3	-
Durum (1)	23.1	17.1	9.8	13.2
Oats (2)	33.5	5.7	12.7	19.5
Flax (1)	12.5	3.7	4.5	5.9

* Number of trials
** The actual rates of application varied somewhat from test to test, but were close to the rate stated (see Appendix for individual data)

A comparison of soil test and general recommendations was available in 19 of the V.L.A. tests. Eleven of the trials were with wheat, four with barley, two with Durum wheat, and one each with oats and flax. The average yield increases (Table 4) indicate that approximately two bushels/acre more was obtained by using the soil test recommendation rather than the general recommendations. At the prices* indicated below, the use of the soil test recommendation would have resulted in approximately $1.70/acre greater profits than the use of the general recommendation. This is considerably less than the $4.00/acre differential in favor of the soil test which was noted for similar experiments conducted in 1968.

*Wheat $1.60/bushel, Oats $0.50/bushel, Barley $1.00/bushel, Flax $3.00/bushel.
11-48-0 $111.00/ton, 23-23-0 $103.00/ton, 34-0-0 $89.50/ton, 11-55-0 $121.50/ton, 46-0-0 $109.00/ton.

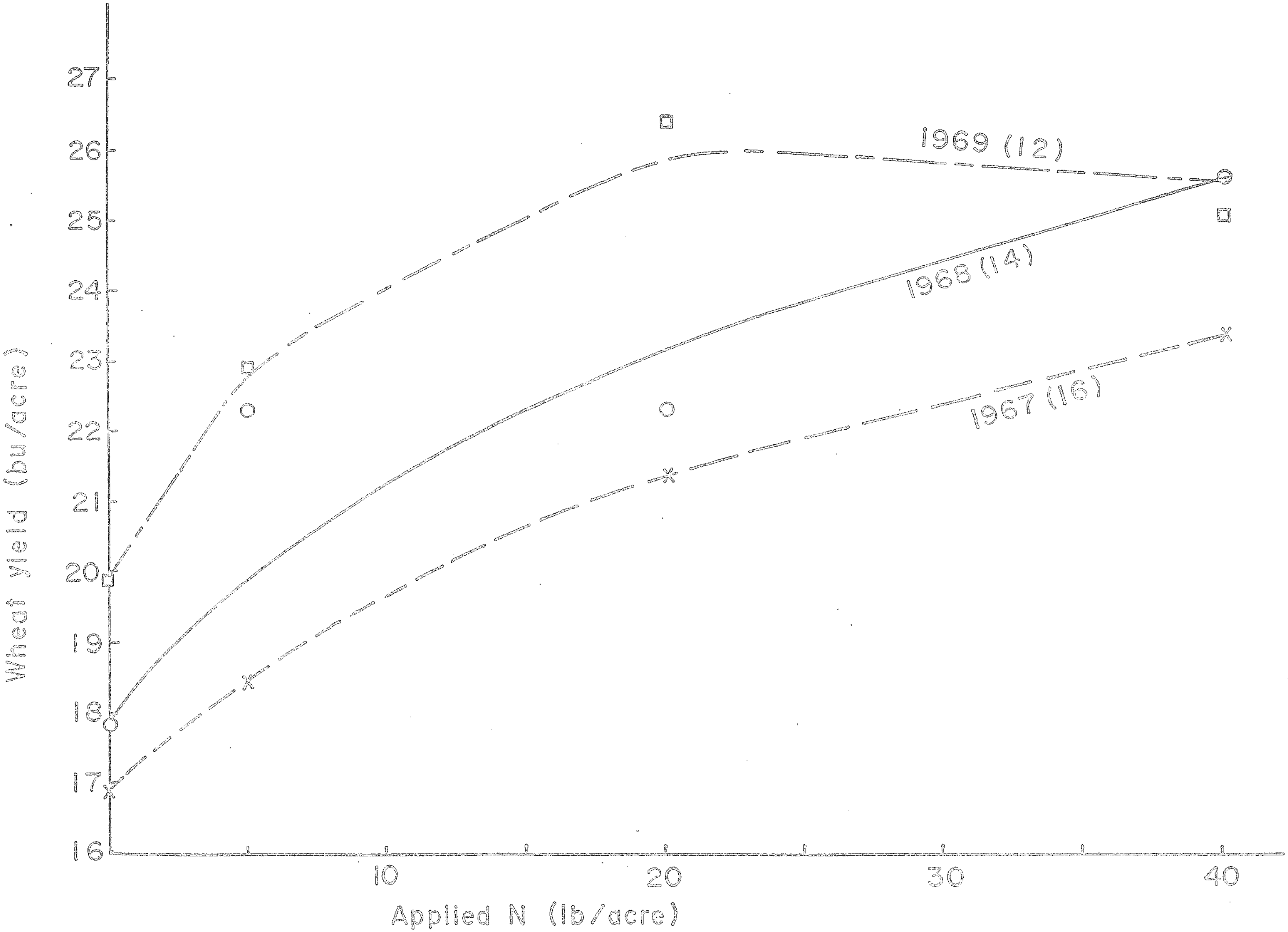

Figure 1. Response of wheat to nitrogen in 1967, 1968 and 1969 - V.L.A. co-operative tests

Table 4. Comparisons of increases and profits from soil test (fall) and general recommendations for V.L.A. co-operative tests.

Advisor	Farmer	Check Yield bu/acre	Crop	Yield Increase: Soil Test Recom.	Yield Increase: General Recom.	Increase Soil Test over Gen. Recom.	Profit Soil Test over Gen. ($/acre)
Baker	Hayward	23.0	Wheat	5.0	0.0*	5.0	4.05
Cox	Ford	13.6	Wheat	9.6	13.9	-4.3	-0.95
Draftenza	Denis	30.2	Durum	16.3	0.0*	16.3	21.56
Kendel	Tosh	12.5	Flax	5.4	4.5	0.9	-0.76
King	Craig	23.1	Durum	13.2	9.8	3.4	2.38
Laing	Boechler	14.9	Barley	17.4	7.9	9.5	3.58
MacKay	Stadnick	16.7	Wheat	-1.2	9.3	-8.1	-3.12
McLeod	Beddome	17.5	Wheat	-2.3	4.1	-6.4	-3.15
Murch	Adair	27.9	Barley	10.4	-0.6	11.0	5.02
Peace	Porter	30.7	Barley	13.1	12.2	0.9	-2.78
Puckey	Nowosad	18.9	Wheat	3.4	3.9	-0.5	-1.78
Salkeld	Keith	31.5	Wheat	-0.3	7.1	-7.4	-0.49
Sherwin	Selvig	36.4	Barley	5.6	0.0*	5.6	0.09
Sikora	Kulovany	30.9	Oats	4.4	2.4	2.0	-2.12
Simpson	Zunti	20.8	Wheat	10.6	9.8	0.8	0.37
Steabner	Peckham	25.4	Wheat	4.8	3.1	1.7	2.26
Steenson	Frolek	18.7	Wheat	6.6	9.0	-2.4	-1.66
White	Hooper	13.3	Wheat	12.8	4.2	8.6	8.65
Zinkhan	Currie	15.6	Wheat	8.9	4.2	4.7	4.21
Average		22.3		7.7	5.5	2.0	1.85

*The general recommendation was for no fertilizer.

The soil test recommendation resulted in higher yields than the general recommendation in 10 of the 19 tests; the trend was reversed in five of the tests, and in four of the tests the differential in yield was less than one bushel/acre. Using the prices indicated, returns favored the soil test recommendation in 8 of the 19 tests. On 6 trials, the general recommendation gave better returns, while on the other five trials, returns were similar for both applications.

1.2 Potassium

PURPOSE

To establish response patterns to potassium and to evaluate current soil test benchmarks for potassium.

EXPERIMENTAL METHODS

Fields for investigation were selected for the most part from samples submitted to the Soil Testing Laboratory in the fall of 1968. The plot area was selected within the field and ten sampling sites (replicates) were selected. Composite soil samples were taken across the width of the plot at each sampling site prior to fertilizer application or seeding. The three standard depths (0-6", 6-12" and 12-24") were used. The same ten sites (replicates) served as sites for yield measurement in the fall.

Nitrogen and phosphorus were applied to the entire plot area (72' x $\frac{1}{2}$ mile) at the rate recommended on the basis of the soil test. If broadcast nitrogen was required, it was applied with department equipment. All seeding operations and nitrogen and phosphorus applications (other than broadcast nitrogen) were carried out with farmers' equipment. Ammonium nitrate (34-0-0) was the source of nitrogen and monoammonium phosphate (11-48-0) was the source of phosphorus. The potash (0-0-60) was broadcast prior to seeding at rates to supply 30, 60, 120 and 240 lb K_2O/acre. The broadcast applications were with a trailer-mounted Cominco 70 fertilizer attachment. Eleven trials were seeded and eight were harvested.

RESULTS

The comparison of fall and spring sampling (Table 5) for the potassium and sulfur trials indicate reasonable agreement for phosphorus and potassium in most instances. It should be recalled that these data compare the fall (1968) field samples with the samples from the trial area in the spring. Therefore, certain discrepancies are to be expected. The comparisons for nitrogen show similar spring-fall values in some instances, but very large increases from fall to spring at some locations. This relationship confirms the data from the V.L.A. tests and further supports the conclusion that more basic information is required to elucidate the factors responsible for the nitrate changes. The potassium and sulfur trials were all located in northeastern Saskatchewan, and many were on Carrot River soils. Carrot River soils are characterized by varying degrees of peat on the surface. Peaty areas invariably give very high nitrate nitrogen tests. Therefore, the number of peaty areas included in the sampling pattern would have a profound affect on the value obtained. This may, in part, explain the discrepancies in the nitrogen tests.

The yield data (Table 6) show that barley responds well to added potassium when soil tests are in the low or very low ranges. The response curves for the two trials with potassium soil tests of 52 and 60 lb K/acre were almost identical. The highest yield of barley obtained in these two experiments was approximately 45 bushels per acre. This is about 10 to 12 bushels/acre less than yields obtained in 1968 on similar soils with similar nutrient applications. Drought in the early part of the growing season, combined with strong winds, resulted in slow growth and considerable wind damage in some instances.

Table 5. Comparison of fall and spring soil tests for potassium, potassium-sulfur, and nitrogen-sulfur trials*

Farmer	Nitrate Nitrogen lb/acre 0-24"		Available P lb/acre 0-6"		Available K lb/acre 0-6"	
	Fall/68	Spring/69	Fall/68	Spring/69	Fall/68	Spring/69
			POTASSIUM TRIALS			
Arnold	70	144	9	17	28	85
Bashforth	-	89	-	10	-	207
Cherepuschak	72	177	11	24	40	234
Ewanus	49	59	12	21	188	420
Gawyuk	17	92	12	10	48	60
Ernie Kozun	19	22	15	13	76	79
Eugene Kozun	20	76	9	6	64	51
Nick Kozun	120+	144	10	11	64	50
Skogsrud	-	75	-	22	-	237
Ken Stafford	39	46	7	16	44	74
Les Stafford	40	50	20	20	40	68
			NITROGEN-SULFUR TRIALS			
Gordon	-	25	-	59	-	280
Rediger	24	44	-	12	-	108
Romaniuk	12	225	28	24	304	158
Earl Stafford	29	49	21	31	212	224
Warnock	20	24	46	24	356	214
			POTASSIUM-SULFUR TRIALS			
Ewanus	-	19	-	25	-	310
Rediger	55	125	19	29	84	89

*Note that these data compare the fall <u>field</u> values to those obtained from sampling the <u>trial</u> area in the spring.

Table 6. Yield response of wheat, barley and oats to potassium fertlization (yield in bu/acre)

Farmer	Soil Type	Crop	Nitrogen+ Phosphorus Yield*	Yield Increase to 0-0-60 @ 50 lb/acre	100	200	400	Available K lb/acre Spring**
Eugene Kozun	Cr:vl	Barley	24.4	7.5	10.4	11.5	20.1	51
Gawyuk	Cr:vl	Barley	24.9	7.8	12.3	12.1	18.8	60
Cherepuschak	Cr:vl	Barley	34.3	13.7	6.5	13.5	-8.8	234
Ernie Kozun	Cr:vl	Wheat	35.1	-1.4	3.2	2.7	3.6	79
Ewanus	Sy:vl	Wheat	31.7	0.9	0.7	1.2	4.3	420
Skogsrud	Wv:l	Wheat	42.4	0.9	-3.3	3.0	4.9	237
Les Stafford	Lc:fl	Oats	59.7	3.7	10.9	2.6	19.5	68
Bashforth	Wv:l	Oats	54.0	6.9	1.4	-5.2	-1.9	207

*Nitrogen and phosphorus were applied to the entire plot area at the rates recommended on the basis of the soil test.

**Sodium bicarbonate extraction.

The third trial with barley (Cherepuschak plot) with a potassium soil test of 162 lb K/acre exhibited a very erratic response pattern. Wind damage was severe at this site; to the extent that the crop on four of the replicates was completely destroyed and only six replicates were harvested.

Wheat appeared to be much less sensitive to low levels of available potassium than was barley. A wheat yield of 35.1 bu/acre with a soil test level of 79 lb K/acre (Ernie Kozun plot) indicates that low levels of potassium are not restricting wheat yields to the same extent that barley yields are affected. A test with wheat in 1968, with a similar soil test level, resulted in a yield of only 5.4 bu/acre without added potassium, but frost had seriously reduced yield in that case.

Oats appear to respond well to added potassium when soil test levels are very low. However, there was only one trial (Les Stafford) with oats on a very low potassium soil and the response pattern on this site was erratic. Therefore, more data would be required to make firm conclusions regarding the potassium requirements of oats.

Rapeseed was the test crop seeded at one site with a soil test level of 50 lb K/acre. Wind erosion completely destroyed the original stand and reseeding was required about June 10. Visual observation in July and early August showed strong response to added potassium. Unfortunately, the plot was not harvested, so no yield data was obtained. However, it is possible that a deficiency of potassium is limiting yields of rapeseed in at least a small portion of the dominant rapeseed-growing area of the province.

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

1. Barley yields are severely reduced when available soil potassium values are less than 100 lb K/acre. Wheat yields are not affected to the same extent as barley.
2. There is a possibility that oat and rapeseed yields also are affected by low soil potassium levels, but much more data is required to confirm this conclusion.
3. More data should be obtained for barley in the higher potassium soil test ranges.
4. Very little information is available on the relative efficiencies of seed-placed and broadcast potassium. Research should be initiated to determine the effect of placement.
5. No information is available on the extent to which yields of forage crops and specialty crops are being reduced by potassium deficiencies. Research on these crops should be initiated.
6. No information has as yet been obtained on the residual effects of high rates of broadcast potassium.

2. EVALUATION OF SOURCES AND PLACEMENT OF NUTRIENTS

2.1 Comparative availability of monoammonium phosphate and ammonium polyphosphate for wheat, barley, rapeseed and mustard

2.1.1 Field scale trials

Five field scale trials were laid down in the Dark Brown and Black soil zones in which monoammonium phosphate (11-48-0) was compared to ammonium polyphosphate (15-60-0). Three of the trials were with wheat and one each with barley and mustard. Department equipment* was used for all operations and the seeding was done with the drill in all cases. The experimental design consisted of standard strip tests with ten sites (replicates) selected for soil sampling and yield determinations. Composite soil samples were taken across the width of the plot at each of the ten sites. The standard depths (0-6", 6-12", 12-24") were used.

All fertilizer was placed with the seed to supply 15, 25, and 40 lb P_2O_5/acre. The strips with 11-48-0 and 15-60-0 at the same rate of P_2O_5 were placed adjacent to one another.

The results (Table 7) indicate little difference in the efficiency of the two sources of phosphorus. The average results for wheat show a trend towards the polyphosphate source being slightly inferior, but the differences are not significant.

*In 1969, the Department equipment consisted of:
1) a Ford 3000 diesel tractor
2) an International Harvester Company #10, 8-foot double disc drill
3) a Massey Ferguson #36, 9-foot discer
4) two four-foot Flexicoil packers

Table 7. Monoammonium phosphate (11-48-0) and ammonium polyphosphate (15-60-0) as sources of phosphorus for wheat, barley and mustard (strip tests)

					Yield Increase to					
					15 lb P_2O_5 as		25 lb P_2O_5 as		40 lb P_2O_5 as	
Farmer	Soil Type	Available P lb/acre 0-6"	Crop	Check Yield bu/ac	11-48-0	15-60-0	11-48-0	15-60-0	11-48-0	15-60-0
Bellamy	M:sicl	18	Wheat	34.5	6.4	3.8	5.0	6.0	10.9	6.8
Popoff	E:cl	23	Wheat	37.5	0.8	2.3	4.0	2.1	4.2	3.0
Roth	B:cl	14	Wheat	22.1	9.0	6.4	8.4	7.0	10.3	11.1
		Average:		31.4	5.4	4.1	5.8	5.0	8.4	6.9
Roth	B:cl	24	Barley	47.1	20.8	17.5	17.3	15.4	23.5	17.1
Jensen	R:hvc	27	Mustard	20.2	-2.4	-0.8	7.1	2.1	-0.2	2.2

The one trial with barley shows that 11-48-0 was slightly superior to 15-60-0. The trial with mustard suffered severe hail damage in late July. The damage was slight at 3 of the 10 replicates, so these three replicates were harvested. Little generalization can be made on the basis of three replications from a single trial. However, plot visits early in the growing season did show visual response, and it is likely that mustard will respond to added phosphorus at soil test levels similar to those encountered in this experiment.

The 1969 results confirm earlier work (see 1968 Soil-Plant Nutrient Research Report) that ammonium polyphosphate is a suitable source of phosphorus for Saskatchewan crops and conditions.

2.1.2 Rod-row experiments using P^{32} (by J.M. Sadler)

PURPOSE

To compare the effectiveness of the standard orthophosphate fertilizer, monoammonium phosphate* (12-62-0) with the polyphosphate fertilizer ammonium polyphosphate (17-63-0) as sources of phosphorus for wheat and rapeseed.

FIELD EXPERIMENTAL METHODS

Two experiments, one with 'Manitou' wheat, the other with 'Echo' rapeseed, were conducted on each of three different soil types; a Weyburn Orthic Dark Brown clay loam, a Weyburn Orthic Gleysol clay loam and a Carrot River Dark Grey Wooded sandy loam. The experiments were set up employing a 4 replicate split plot design, with the 4 treatment levels (0, 15, 25 and 40 lb P_2O_5/acre placed with the seed) as the main plots randomized within each replicate, and the two fertilizers, monoammonium phosphate (MAP) and ammonium polyphosphate (APP) as the subplots giving a total of 32 subplots/crop/soil type. Eight 4-foot neutron moisture meter tubes were placed adjacent to the plots on each of the soil types (two per replicate shared between the two experiments on each site) at time of seeding. The soil removed in the placement of these tubes was analyzed for pH, conductivity, NO_3-N and available P and K levels, and for texture.

*The P^{32} tagged fertilizers were prepared for the department by the Tennessee Valley Authority, Muscle Shoals, Alabama. In contrast to previous experiments, the polyphosphate used in the 1969 experiments had a considerably lower orthophosphate content (T.V.A. analyses: ortho-P, 7.9%; Pyro-P, 73.8%; tripoly-P, 6.9%; and other forms 11.2% fertilizer P content).

Table 8. Soil test results for P^{32} rod-row experiments (average of 4 replicates)

Farmer Soil Type	Location	Depth (inches)	pH	Cond. (mmhos/cm)	lb/acre NO_3-N	P	K
Stevenson Weyburn Orthic Dark Brown:cl	NW 3-37-4-W3	0- 6	6.9	.05	28	17	530
		6-12	7.2	.09	24	10	338
		12-24	7.7	.13	56	14	716
Stevenson Weyburn Orthic Gleysol:cl	NW 3-37-4-W3	0- 6	6.6	.04	42	34	829
		6-12	6.1	.03	22	11	503
		12-24	6.6	.03	48	16	900
Rediger Carrot River Dark Grey Wooded:sl	SE 12-49-12-W2	0- 6	7.7	.07	91	22	85
		6-12	8.0	.03	16	8	50
		12-24	8.2	.03	26	10	80

The soil test data (Table 8) indicated that levels of NO_3-N and K were more than adequate on the three locations used, with the exception of the Carrot River soil. On this site, 163 lb K_2SO_4/acre was broadcast at seeding time to counter an indicated potassium deficiency. Sulphur studies on this same site showed that the soil was deficient in sulphur, hence the choice of K_2SO_4 as the source of K.

The fertilizer was placed with the seed using a Bolens Ridemaster 6 row, V-belt seeder set for 7" spacings. Each subplot, consisted of six 25-foot rows with the P^{32} tagged fertilizer treatment being placed in rows 2 and 5, while the remaining 4 rows (guard rows) received the same level of phosphate application to prevent cross feeding. Although no nitrogen application was required, all the P treatment levels were brought up to the same level of N (10 lb N/acre) by mixing the required amount of NH_4NO_3 with the P fertilizer before application.

In addition to the six experiments previously outlined, a smaller series of experiments with wheat were conducted on an Oxbow association catenary sequence consisting of a Calcareous, an Orthic and an Eluviated Black subgroup profile and a Low Humic Eluviated Gleysol subgroup profile. Seeding and placement of fertilizer was carried out in the same manner as for the other experiments, except that there was only one level of application for each of the two fertilizers (23 lb P_2O_5/acre) and there were only two replicates per subgroup profile. In accordance with soil test recommendations, nitrogen (as 34-0-0) was broadcast at 40 lb N/acre prior to seeding.

The P^{32} tagged crop rows were sampled at approximately six weeks from emergence and again at maturity. Seed germination for the wheat was even and it was possible to obtain yield results along with total P content and 'A' values for this crop. At six weeks, a 2-foot row sample was taken at random from the two tagged rows and bulked for each subplot. The same procedure was carried out at maturity, taking 7.5 ft. row samples from the tagged rows. There was, however, a marked unevenness in the germination of the rapeseed which precluded the obtaining of satisfactory yield results. Approximately six individual rapeseed plants were taken at random at both six weeks and maturity from each of the two tagged rows and bulked for each subplot.

LABORATORY EXPERIMENTAL METHODS

The field samples were first dried; only the wheat samples were weighed. The samples were then ground to pass a 1 mm sieve in a Wiley #3 Mill. A duplicate 1 to 2 gm subsample of each sample was wet ashed. A predigestion was carried out with 10 ml of concentrated HNO_3 on a hot plate until almost dry, prior to digestion in 10 ml of tertiary acid (a mixture of concentrated HNO_3, H_2SO_4 and 70% $HClO_4$ in a 10:1:4 ratio) on a hot plate until a clear solution remained. At this stage, the subsample was filtered into a 50 ml volumetric flask and made up to volume in deionized water, ready for total P and P^{32} assay.

A 20:1 dilution of the digested samples was carried out on an auto-dilutor prior to total plant P determination on a Technicon Auto-Analyzer employing the Murphy and Riley sulphomolybdate-ascorbic acid colorimetric method[1].

The P^{32} activity of the same digested subsamples was determined on a Picker Nuclear Liquimat 220 Liquid Scintillation Counter using the Triton X-100 Scintillant method described by Turner[2]. Using a Hamilton gas-tight syringe fitted with Chaney adaptor, a 1 ml aliquot of the sample was transferred to a scintillation vial containing 15 ml of the scintillant and the sample counted for 20 minutes.

Digested samples of the P^{32} tagged fertilizers were run through the same procedures described above to determine their specific activity.

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[1]Murphy, T. and J.P. Riley, 1962. Annal. Chim. Acta. 27: 31-36.
[2]Turner, J.C., 1968. Int. J. App. Rad. Isot. 19: 557-563.

'A' values were calculated from the following formula:

$$\text{'A' value (lb P/acre)} = (Sf/_{Sp} - 1) \cdot X$$

where Sf = Specific activity of the fertilizer

Sp = Specific activity of the plant sample

and X = Rate of applied P fertilizer in lb P/acre

RESULTS

A. Wheat Experiments

The six weeks dry matter yield (Table 9.2) and grain yield results (Table 9.5), whether expressed separately for each main site or averaged for the three sites (Figure 2), indicated that there was very little to choose between MAP and APP as sources of P for wheat. When expressed as total P uptake (dry matter yield x plant P content), the differences between the two phosphorus forms were even less noticeable (Tables 9.1, 9.4 and Figure 3). An interesting feature of these results, whether expressed as total P uptake or as straight yield, was the much smaller increment in crop response between the 15 and 25 lb P_2O_5/acre rates of application for MAP compared with the APP crop response pattern which followed the more usual smooth curve. This led to a crossing over of the response curves for MAP and APP between the 15 and 25 lb P_2O_5/acre rates (e.g. see Figure 2.2).

The general wheat response pattern to MAP and APP was consistent with previous rod-row and strip trial investigations which showed little difference in availability of the two sources. One noticeable anomaly was the lack of grain yield response to MAP at the lowest rate of application on the Rediger site (Table 9.5), while total P uptake in the grain very definitely increased between the

Table 9. P^{32} rod-row experiments with wheat (average of 4 replicates)

		Treatments					
		15 lb P_2O_5/A		25 lb P_2O_5/A		40 lb P_2O_5/A	
Site	Check	MAP	APP	MAP	APP	MAP	APP
		9.1 Total P Uptake at 6 Weeks: lb P/A					
Stevenson Orthic	1.12	2.51	2.48	2.88	3.05	4.15	3.48
Stevenson Gleysol	1.36	2.68	2.38	3.13	2.65	3.47	3.13
Rediger	3.04	3.28	3.76	4.45	4.62	4.66	4.62
		9.2 Dry Matter Yield at 6 Weeks: lb/A					
Stevenson Orthic	497	996	983	1033	1107	1379	1144
Stevenson Gleysol	524	1036	903	1191	933	1124	1175
Rediger	1288	1369	1428	1718	1800	1721	1566
		9.3 'A' Values at 6 Weeks: lb P/A					
Stevenson Orthic		16.0	8.3	12.1	12.5	14.7	14.3
Stevenson Gleysol		13.4	12.4	12.8	13.6	16.8	12.3
Rediger		28.5	30.2	29.7	28.7	28.4	37.0
		9.4 Total Grain P Uptake at Maturity: lb P/A					
Stevenson Orthic	7.61	10.63	10.14	11.02	11.41	11.84	12.07
Stevenson Gleysol	8.58	10.08	10.07	10.45	10.83	11.06	10.86
Rediger	12.96	16.25	17.22	16.45	18.03	19.01	18.23
		9.5 Grain Yield: bu/A					
Stevenson Orthic	32.8	43.3	41.1	46.8	47.4	49.5	49.6
Stevenson Gleysol	36.6	44.1	42.4	43.5	45.2	47.7	47.4
Rediger	44.7	44.8	46.9	45.5	48.8	51.8	48.6
		9.6 'A' Values at Maturity: lb P/A					
Stevenson Orthic		39.6	39.0	46.5	38.1	45.8	36.7
Stevenson Gleysol		37.3	39.8	41.2	56.4	44.1	36.2
Rediger		141.1	77.7	98.8	134.8	113.7	143.0

Figure 2. Average Yield of Wheat for P^{32} Rod-Row Experiments

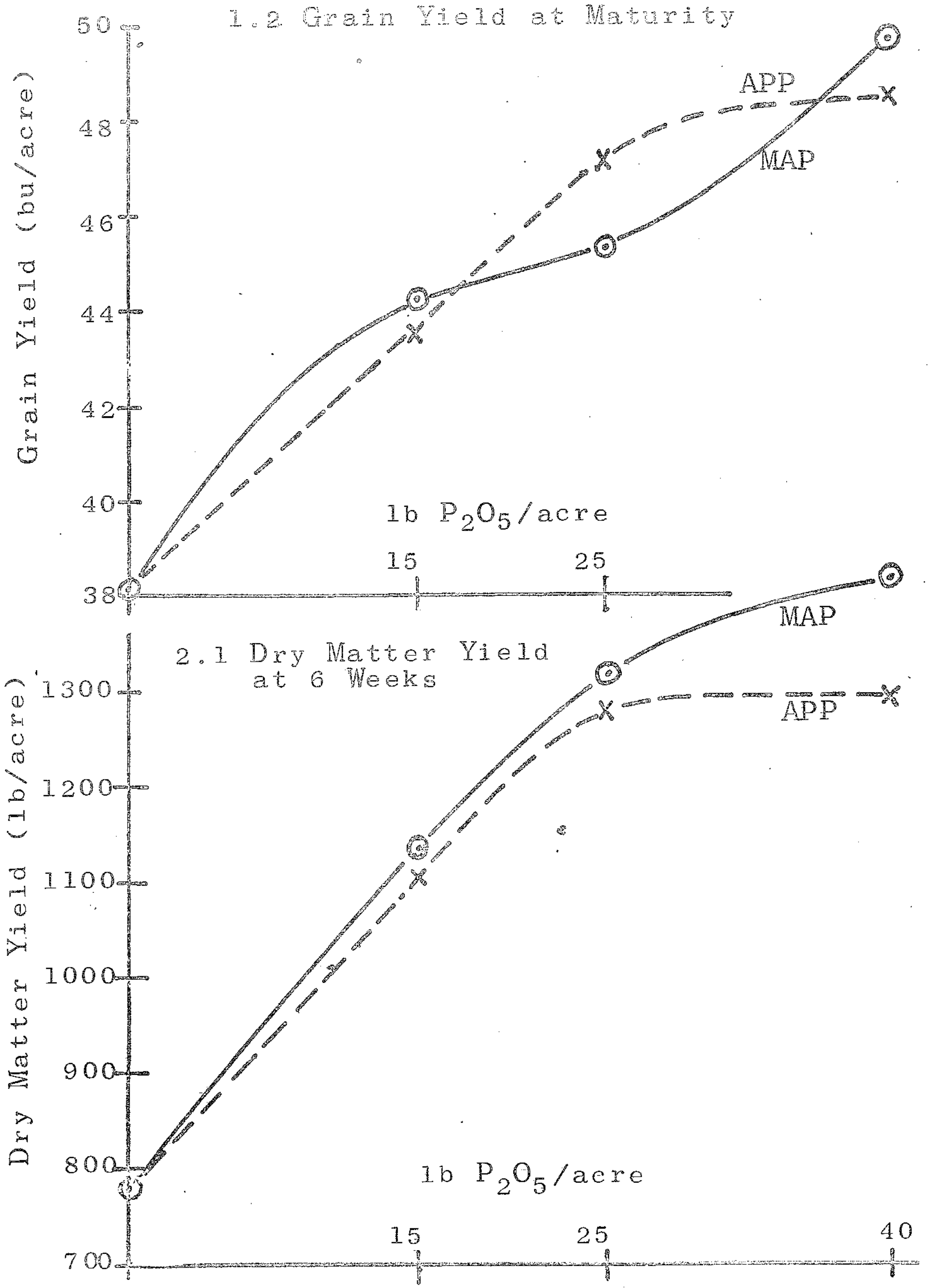
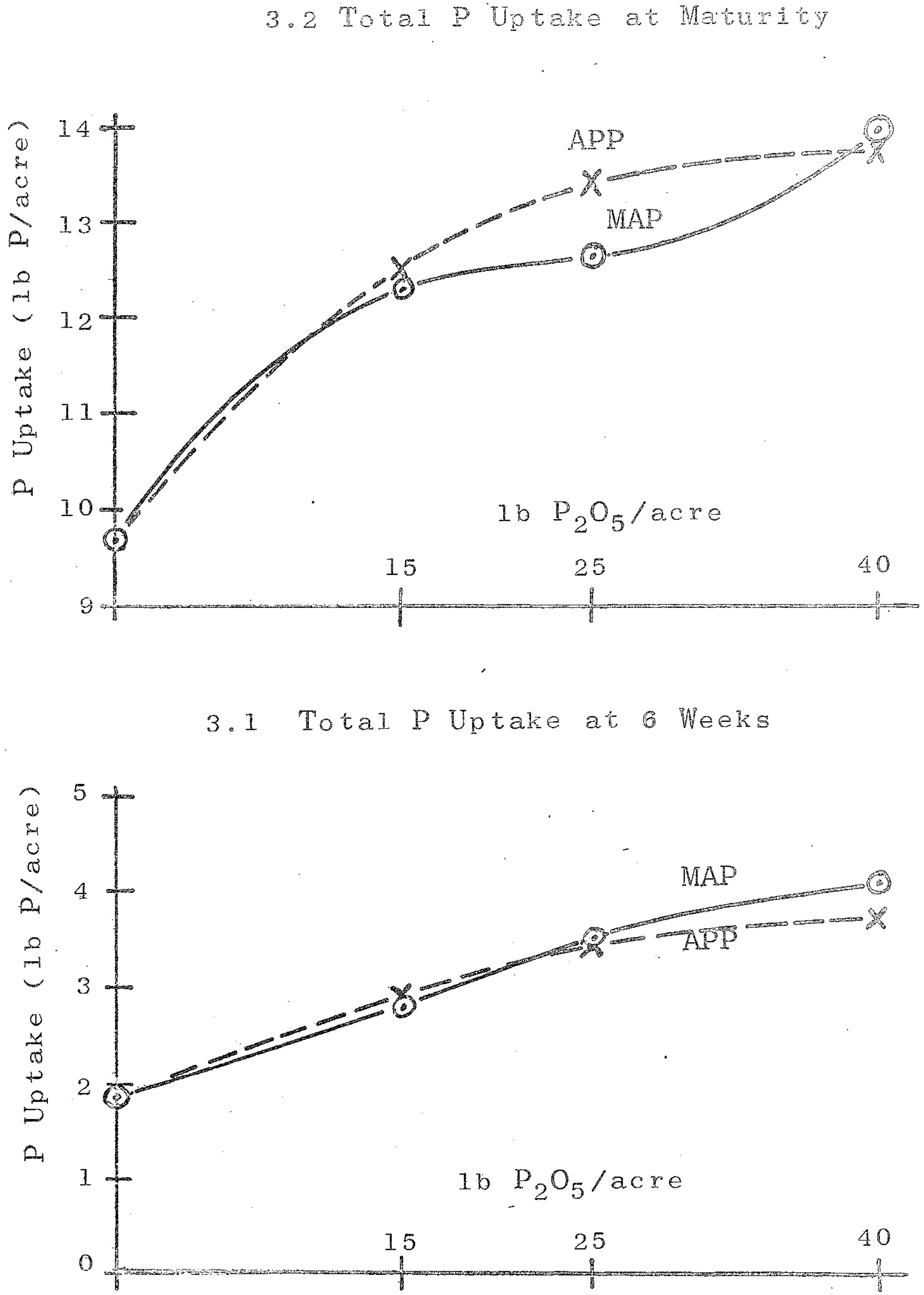


Figure 3. Average Total P Uptake by Wheat for P32 Rod-Row Experiments



check treatment and the 15 lb P_2O_5/acre rate (Table 9.4). This was the only instance of applied P fertilizer causing a marked increase in the P content of wheat plants (from 4.8 mg P/gm grain in the checks to 6.1 mg P/gm grain at 15 lb P_2O_5/acre).

In accord with the theory of 'A' values[1], the wheat 'A' values for the main sites were independent of the rate of P application (Tables 9.3 and 9.6). From the 'A' values averaged over the three P treatment levels, it would appear that MAP and APP were equally available as sources of P for wheat on all three soils at both sampling dates.

The averaged 'A' values for each site, at six weeks and maturity showed a good correlation with crop response to added P and with the yield and total P uptake for the check plots. These results are generally in accord with the soil test P values, except for the Stevenson orthic gleysol (Table 8). This lack of correlation on the gleysol has been noted in previous studies on the relationship between soil test (bicarbonate extraction) P values, crop yield and crop response to added P.

On the Oxbow series of experiments there were marked, but rather inconsistent, differences between the 'A' values for the MAP and APP treatments across the four soil profiles (Table 10).

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[1]Fried, M., and Dean, L.A. 1952. Soil Sci. 73: 263-271.

B. Rapeseed Experiments

From the moderate but consistent differences between the 'A' values for MAP and APP across the three treatment levels for rapeseed at six weeks, it would appear that there was greater utilization of phosphorus from the MAP source than from APP by the rapeseed plants up to the six-weeks stage of growth (Table 11.2). This was corroborated by the P content at six weeks for the Stevenson Orthic soil only (Table 11.1). An interesting feature of the six-weeks results for rapeseed was the increase in 'A' value with increasing rate of P application for both MAP and APP. The tissue P content also showed this effect quite distinctly with an increase of about 35% in the tissue P content between the check and the 40 lb P_2O_5/acre rate on all three soils (Table 11.1).

At maturity, the rapeseed 'A' values were independent of rate of P application (Table 11.4). With the exception of the Stevenson Orthic Gleysol, which showed no real difference between 'A' values for MAP and APP, the position of six weeks was reversed with the rapeseed showing considerably greater overall uptake of phosphorus from APP than from MAP. The P content of the rapeseed (Table 11.3) gave no indication of the apparent greater availability of APP. However, there was once again a marked increase in the P content of the rapeseed with increasing rate of P application.

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

A) On the basis of yield, P uptake and 'A' value results collected over the past three years, APP may be regarded as equal to MAP as a source of P for wheat under most Saskatchewan farming conditions.

Table 10. 'A' values (lb P/acre) on the Oxbow association catenary sequence (average of two replicates)

	Calcareous		Orthic		Eluviated		L.H.E.Gleysol	
	MAP	APP	MAP	APP	MAP	APP	MAP	APP
6 weeks	13.1	15.1	38.5	60.6	-	-	55.5	56.3
Maturity	42.4	47.1	152.5	127.3	75.3	68.3	149.8	86.0

Table 11. P^{32} rod-row experiments with rapeseed (average of four replicates)

		Treatments						Mean of 3 Treatment 'A' Values	
		15 lb P_2O_5/ac		25 lb P_2O_5/ac		40 lb P_2O_5/ac			
Site	Check	MAP	APP	MAP	APP	MAP	APP	MAP	APP
11.1 mg P/gm Dry Plant Tissue at 6 Weeks									
Stevenson Orthic	5.45	6.90	5.93	7.38	6.93	7.35	7.08		
Stevenson Gleysol	5.18	5.56	5.74	6.55	6.06	6.78	6.70		
Rediger*	3.08	3.93	4.13	4.25	4.05	4.35	4.23		
11.2 'A' Values at 6 Weeks: lb P/acre									
Stevenson Orthic		17.5	18.6	32.3	36.5	38.5	41.6	29.4	32.2
Stevenson Gleysol		22.6	35.9	26.8	35.6	44.4	47.3	31.3	39.6
Rediger*		14.1	16.3	20.7	22.2	32.5	38.5	22.4	25.7
11.3 mg P/gm Dry Rapeseed at Maturity									
Stevenson Orthic	6.63	6.83	7.05	7.52	7.28	7.94	7.74		
Stevenson Gleysol	7.28	7.45	7.32	7.66	7.45	8.27	8.35		
Rediger*	6.66	8.76	8.12	8.69	8.58	9.38	9.30		
11.4 'A' Values at Maturity: lb P/acre									
Stevenson Orthic		69.3	39.9	59.9	40.3	80.8	46.2	70.0	42.1
Stevenson Gleysol		40.6	42.3	53.6	52.2	48.4	49.8	47.5	48.1
Rediger*		63.0	29.6	87.6	28.5	59.5	41.6	70.0	33.2

*Results as an average of 3 replicates

Whether APP can compete with ortho-P fertilizer like MAP now in use, will depend on its price and availability to farmers.

B) The 'A' value results indicate that, while MAP was a more available source of P than APP for rapeseed in the early stages of growth, there was greater utilization by rapeseed of APP compared with MAP over the growing season as a whole. Thus, it would appear that further field comparison studies between MAP and APP should be conducted on rapeseed and other major crops as yet not tested.

C) Certain anomalies in the crop uptake patterns of MAP and APP, as revealed by this and other similar studies, would suggest the need for more specialized experiments on P uptake by plants.

2.2 Comparison of seed-placed and broadcast placements of urea and ammonium nitrate using N15

PURPOSES

(1) To compare the relative efficiencies of urea and ammonium nitrate as sources of nitrogen for wheat.

(2) To compare the relative efficiencies of seed-placed and broadcast nitrogen.

EXPERIMENTAL METHODS

A single experiment with wheat was laid down on a Grey Wooded (Waitville loam) stubble soil in which urea was applied at 20 lb N/acre, both seed-placed and broadcast. Ammonium nitrate was applied seed-placed and broadcast at 20 lb N/acre and at 40 and 80 lb N/acre with broadcast placement only. Monoammonium phosphate at 30 lb P_2O_5/acre was applied seed-placed to all treatments.

Nitrogen sources ($N^{15}H_4N^{15}O_3$ and $N^{15}H_2CO\ N^{15}H_2$) with 1 atom % excess N^{15} were used for the tagged experiment. An identical experiment using non-tagged fertilizers was placed adjacent to the tagged experiment. A randomized complete block design was used with four replicates. Therefore, for the purposes of yield comparisons, there were eight replicates (i.e. four with tagged sources and four with non-tagged sources).

A six-row belt seeder with 7-inch spacings was used. The fertilizers were applied to three rows with 15-foot row lengths at each replicate. A 1-foot sample was taken from the tagged experiments at six weeks after seeding. Ten-foot row lengths were cut, from all three rows, at harvest time.

RESULTS

The detailed laboratory analyses for total nitrogen and N^{15} nitrogen (mass spectrometer) are currently in progress. Therefore, the uptake and 'A' value data will be presented in a subsequent report.

The yield data (Table 12) once again demonstrates the extreme nitrogen deficiency of Grey Wooded soils. The broadcast placement of ammonium nitrate was as effective as seed placement, but urea appeared to be more efficient when seed-placed. Further analysis of the N uptake and yield data will be required to determine the significance of the apparent 5.6 bu/acre increase of urea over ammonium nitrate when seed-placed at 20 lb N/acre.

Table 12. Comparison of yield response of wheat to seed-placed and broadcast applications of urea and ammonium nitrate

Wheat Yields (bu/acre)

		20 lb N/acre				N/acre	
		Seed-placed		Broadcast		Broadcast	
	Check	Ammonium Nitrate	Urea	Ammonium Nitrate	Urea	40 lb Ammonium nitrate	80 lb Ammonium nitrate
Tagged	19.3	25.0	33.7	28.5	28.9	41.9	45.8
Non-tagged	16.4	25.6	28.1	27.9	25.4	35.6	47.5
Average	17.8	25.3	30.9	28.2	27.2	38.7	46.6

3. NUTRIENT REQUIREMENTS OF IRRIGATED CROPS

3.1 Nitrogen Requirements of Wheat Under Irrigation

Four trials were laid down in which the response pattern of wheat to nitrogen under irrigated conditions was investigated. Rates of 25, 50, 75 and 100 lb nitrogen/acre were compared. Ammonium nitrate (34-0-0) was the nitrogen source. Two trials were on land irrigated by the border dike method, and two were irrigated by the sprinkler method.

For the sprinkler tests, the nitrogen was broadcast in strips, prior to seeding, with a six-foot truck-mounted Cominco 70 fertilizer attachment. Ten sites (replicates) were selected for spring soil sampling, and these sites were used for yield measurements in the fall. Phosphorus as monoammonium phosphate (11-48-0) was applied with the seed at the soil test recommended rate to the entire test area.

In the tests where border dike irrigation was used, the nitrogen was applied with a four-foot Gandy applicator three to four days after seeding. A randomized block design was used with six replicates. All the replicates were down the same border strip on which no previous broadcast nitrogen had been applied. The individual plots were 30 feet in length. An 18-foot length of the three center drill rows were harvested for yield determinations. Phosphorus was applied at the soil test recommended rate, seed-placed, at the Hauberg site, but no phosphorus was applied at the Carlson site. Approximately 50% hail damage was recorded at the Carlson site in early July.

The results (Table 13) indicate strong responses to added nitrogen in all cases. The average results (Figure 4) indicate that the response curve levels off at 75 lb/acre of applied nitrogen. This is the current soil test recommended rate for soil tests in the very low range. The soils under test here were in the low and medium nitrogen soil test ranges. Therefore, the recommendations for the very low soil test nitrogen ranges may require upward adjustments. It should be noted that the spring nitrogen test for the Hauberg site is open to question. Unfortunately, soil samples were not taken until after seeding. The seeding operation included an application of seed-placed 11-48-0. The soil samples were taken between the drill rows, but the possibility of contamination with in-row fertilizer cannot be totally discounted.

The relatively high yield (30.9 bu/acre) at the Vestre site, with no broadcast nitrogen, deserves comment. On the strip tests, two check strips were harvested. At the Vestre site, the check strip adjacent to the 100 lb nitrogen/acre treatment yielded 35.7 bu/acre, whereas the check strip adjacent to the 25 lb nitrogen/acre rate yielded only 26.1 bu/acre. A field inspection early in July suggested that wind erosion may have displaced some of the applied nitrogen from the 100 lb nitrogen/acre strip and deposited it on the adjacent check strip.

The data clearly indicates that wheat yields under irrigation are severely restricted by nitrogen deficiencies and that rates of at least 75 lb N/acre will be required to overcome these deficiencies. The maximum yields obtained in the tests reported here (about 40 bu/acre) are not likely to be acceptable under irrigated

Table 13. Response of wheat to nitrogen under irrigation

armer	Irrigation Type	Soil Type	NO_3-N lb/acre 0-24"	Check Yield*	Yield Increase to N at 25 lb/acre	50	75	100
arlson	Border	Br:vl	40	21.8	3.0	12.3	15.5	18.3
auberg	Border	Br:vl	36	18.2	7.0	18.6	18.3	25.3
roeker	Sprinkler	A:sl	28	21.0	3.4	10.9	16.0	14.6
estre	Sprinkler	A:sl	39	30.9	8.6	4.7	13.4	8.3

*11-48-0 was applied at the soil test recommended rate at all sites except Carlson, in which no additional fertilizer was applied.

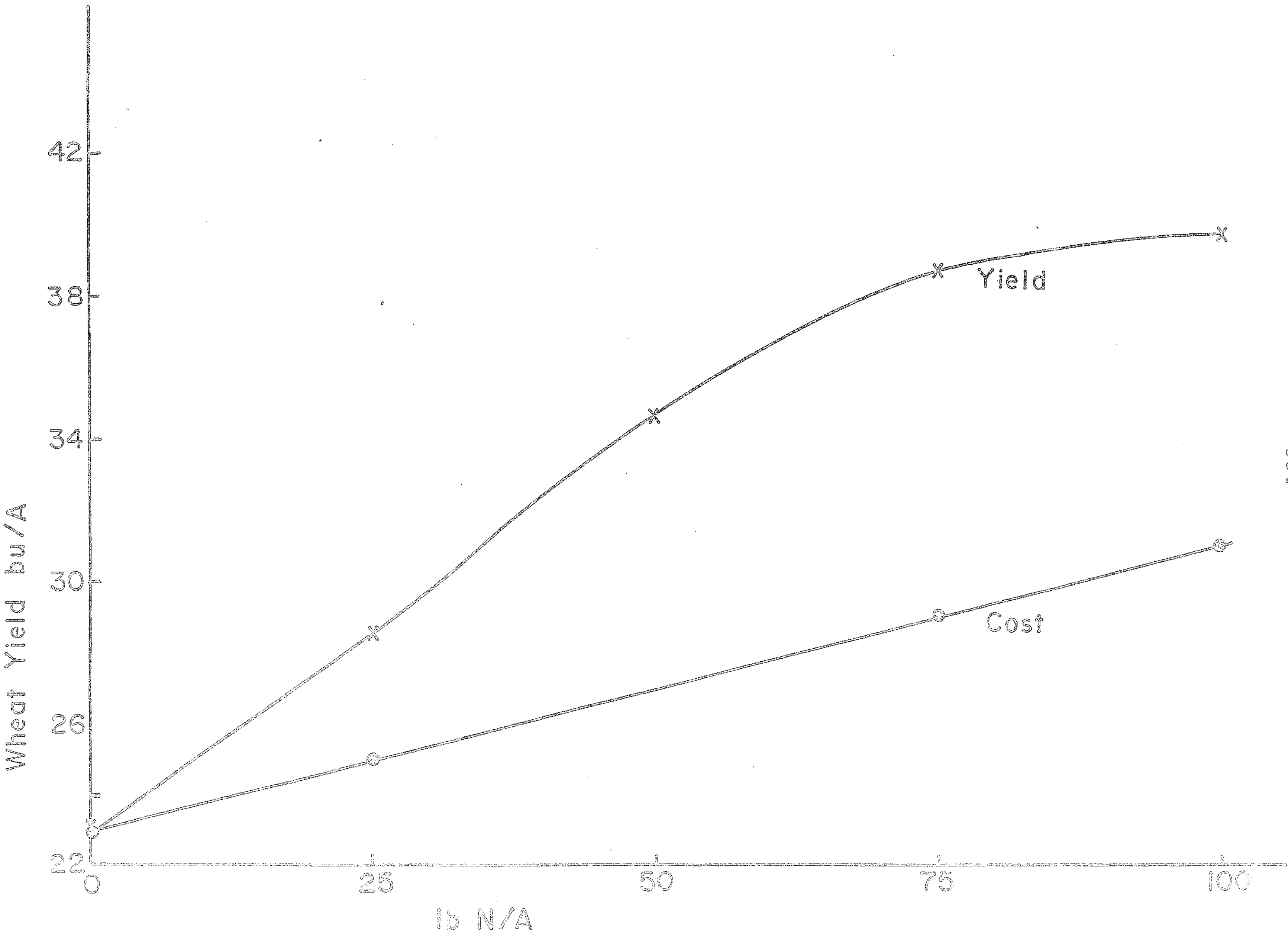

Figure 4. Response of irrigated wheat to nitrogen.

conditions. Further research will be necessary to determine the nutrient requirements of a variety of irrigated crops.

3.2 Nitrogen and phosphorus requirements of alfalfa under irrigation

PURPOSE

To establish the nutrient requirements of irrigated forage crops in relation to soil test levels.

EXPERIMENTAL METHODS

Sites for experimentation were selected within the South Saskatchewan River Irrigation Project on Crown land operated by the Saskatchewan Department of Agriculture. The sites (Table 14) were selected to give some range in soil characteristics and irrigation types. Sites 1 and 2 were Bradwell soils, but extremely sandy layers were encountered at approximately 18" to 20" depth. Site 2 was in a levelled area where the A horizon (surface soil) had been removed. Unfortunately, this removal was not completely uniform over all replicates and this characteristic confounded the interpretation of the results. Site 3 was Elstow soil with clay textures at depth (18" to 24").

Beaver alfalfa had been seeded on all sites in 1968. A very heavy companion crop of oats was grown in 1968 at Site 3, and this left a heavy oat stubble. Some of the oat straw was present in the samples collected at the June cut on Site 3.

The fertilizer treatments were arranged in a randomized complete block design with four replicates. The nitrogen and phosphorus experiments were placed adjacent to one another at each of the three sites. All fertilizer materials were broadcast on the

Table 14. Site characteristics of soils selected for irrigated alfalfa study

	Site 1	Site 2	Site 3
Legal Location	SE21-28-7 W3	NE21-28-7-W3	NE16-28-7-W3
C. and D. Plot No.	-	1	4
Irrigation Type	Sprinkler	Border Dike	Border Dike
Soil Association	Bradwell	Bradwell	Elstow
Texture	Very fine sandy loam	Very fine sandy clay loam	Clay loam
Nitrate Nitrogen (lb/acre 0-24")	19	35	44
Available Phosphorus (lb/acre 0-6")	10	7	14
Available Potassium (lb/acre 0-6")	372	260	616
A horizon	Intact	Removed	Intact

surface with a four-foot Gandy applicator on April 16 and April 17, 1969. Ammonium nitrate (34-0-0) and triple super phosphate (0-45-0) were the sources of nitrogen and phosphorus respectively. Nitrogen was applied at rates of 20, 30, 40, 60 and 80 lb/acre, with and without 90 lb P_2O_5/acre. Phosphorus was applied at 20, 40, 60, 90 and 120 lb P_2O_5/acre, with and without 60 lb N/acre.

Soil samples were taken (0-6", 6-12" and 12-24") from each replicate prior to fertilizing. At the time the experiments were laid down, the surface soils were at field capacity. Frost was encountered within the two-foot profile (at 20-24") in some instances.

Each plot was 5 feet by 20 feet. Samples were cut at a height of 3 inches, with a two-foot Mott forage plot harvester over a 16-foot length. A wet weight of the samples cut was taken in the field immediately after cutting. A 500-gram subsample was taken and returned to the laboratory for drying. A dry weight of the subsample was taken, after which the samples were ground in preparation for quality analysis. To date, the quality analysis has not been conducted. Harvest dates were June 25 and 26, 1969 for the first cut, and August 21 and 22, 1969 for the second cut. At Site 1, only two of the four replicates were harvested in August.

RESULTS

As expected, the results (Table 15) indicate no response of alfalfa to applied nitrogen. Visual observation early in the growing season indicated some stimulation in early growth due to nitrogen. However, this did not continue until the first cut in June, and no significant yield increases to nitrogen were recorded.

Table 15. Response of irrigated alfalfa to phosphorus and nitrogen

lb N/acre	lb P_2O_5 per acre	Dry Matter Yields, tons/acre: Site 1 June	Site 1 August	Site 2 June	Site 2 August	Site 3 June	Site 3 August
		A. PHOSPHORUS EXPERIMENTS					
0	0	1.31	1.49	0.86	1.01	1.26	1.29
0	20	1.44	1.68	0.60	0.91	1.13	1.34
0	40	1.48	1.59	0.78	1.07	1.32	1.39
0	60	1.55	1.69	0.73	1.18	1.18	1.55
0	90	1.55	1.74	1.15	1.37	1.24	1.45
0	120	1.68	1.53	1.29	1.36	1.66	1.61
60	0	1.27	1.44	0.58	1.09	1.22	1.35
60	20	1.37	1.48	0.98	1.05	1.24	1.43
60	40	1.49	1.70	0.84	1.25	1.43	1.46
60	60	1.78	1.56	0.72	1.21	1.45	1.48
60	90	1.80	1.53	1.06	1.38	1.66	1.59
60	120	1.66	1.69	1.04	1.33	1.66	1.64
L.S.D.(P = 0.05)		0.18	N.S.	N.S.	0.28	0.26	0.23
		B. NITROGEN EXPERIMENTS					
0	0	1.36	1.51	1.04	1.08	1.07	1.21
20	0	1.38	1.54	0.83	1.10	1.18	1.23
30	0	1.31	1.44	0.93	1.15	1.12	1.17
40	0	1.34	1.44	0.89	1.08	1.20	1.15
60	0	1.27	1.62	0.73	0.96	1.15	1.18
80	0	1.38	1.48	0.90	1.09	1.26	1.26
0	90	1.66	2.14	1.17	1.61	1.50	1.53
20	90	1.61	1.80	1.06	1.48	1.53	1.44
30	90	1.71	1.77	0.98	1.44	1.59	1.51
40	90	1.61	1.90	1.57	1.44	1.66	1.41
60	90	1.73	1.91	1.12	1.47	1.70	1.57
80	90	1.69	2.03	1.18	1.41	1.62	1.47
L.S.D.(P = 0.05)		0.20	N.S.	N.S.	0.32	0.35	0.23

Although phosphate response was recorded at all three sites, there was little opportunity to relate the response patterns to soil available phosphorus, as all of the sites were in the very low soil test range.

A normal response curve was obtained at Site 1 where sprinkler irrigation was used and no soil disturbance had taken place (Figure 5). At Site 1, the combined yield increases (June and August cuts) to 60 lb P_2O_5/acre would have resulted in a profit* to fertilization of approximately $5.00/acre.

The extreme variability at Site 2 was not totally unexpected in light of the variability in removal of A horizon noted above. The removal of the A horizon was complete over all treatments on replicates 1 and 2 at Site 2. Analysis of the two replicates probably provides a better estimate of the phosphorus requirements of alfalfa grown under irrigation where levelling operations have removed the A horizon. The results for these conditions (Figure 6) show that phosphorus deficiency severely restricts yields and that the addition of approximately 90 lb P_2O_5/acre would be highly profitable.

The response pattern at Site 3 was similar to that obtained at the other sites. However, on this plot, yield increases were greatest for the 120 lb P_2O_5/acre rate. Further research will be required to fully understand the nature of the response curve for phosphate fertilization of forage crops.

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*Hay = $22.00/ton P_2O_5 = $0.09/lb

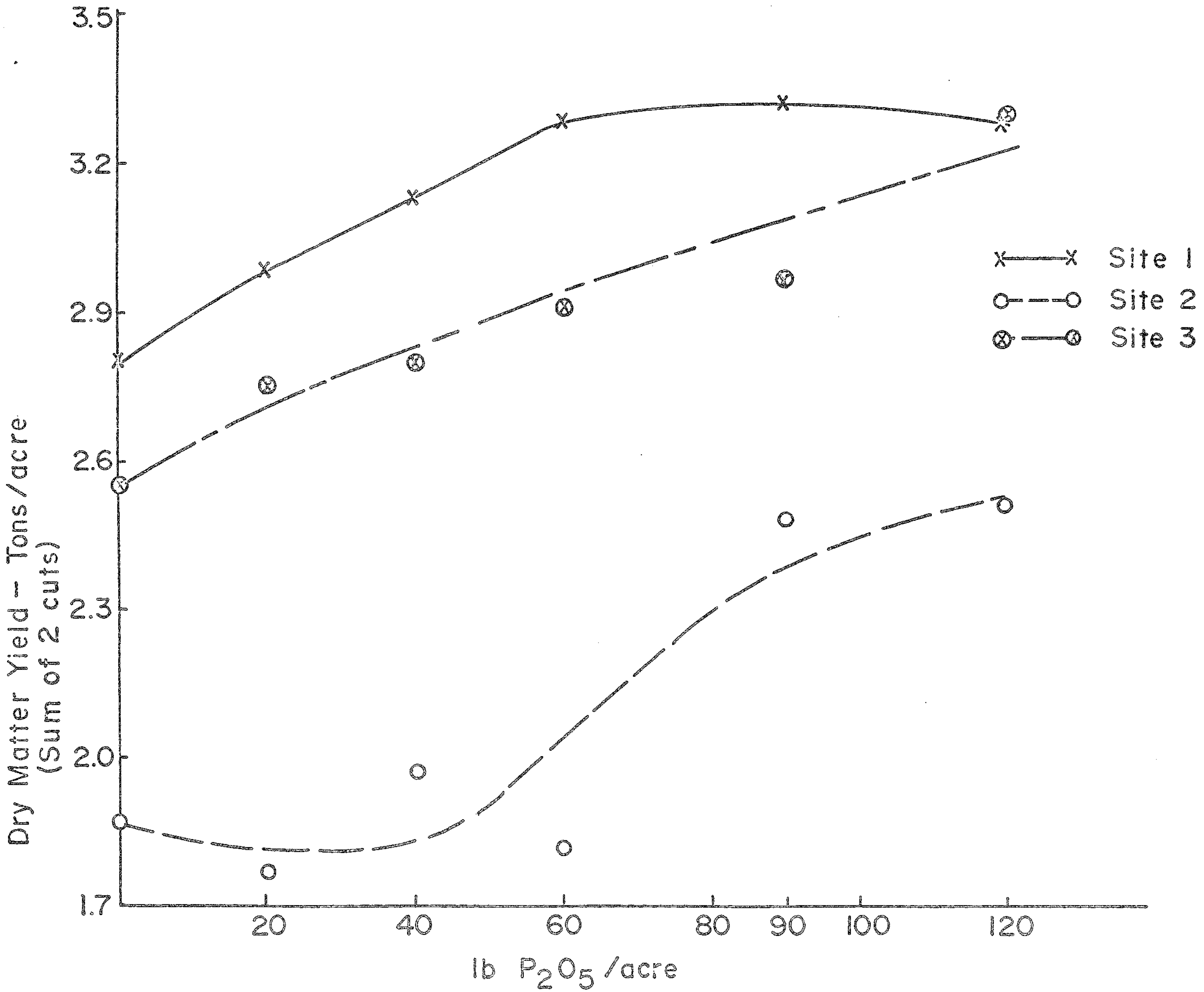

Figure 5. Response of irrigated alfalfa to phosphorus.
(Average of 60 lb N/acre and no nitrogen treatments)

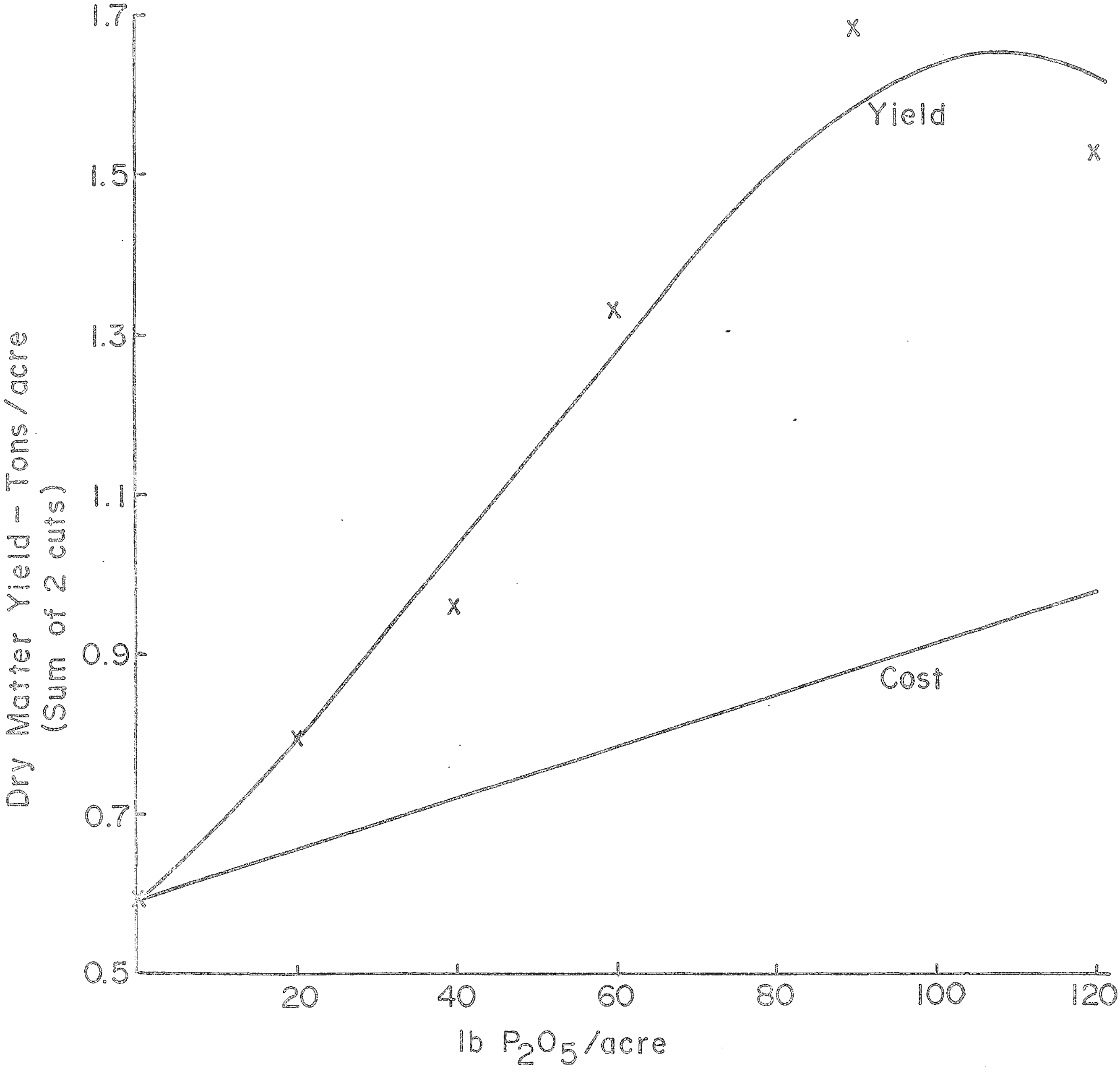

Figure 6. Phosphate response of irrigated alfalfa on a Bradwell soil with the A horizon removed.
(Replicates 1 and 2 at site 2)

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

1. Nitrogen deficiencies do not limit the yields of alfalfa in the year following establishment. There would be little value in continuing nitrogen in future experiments with established alfalfa stands. However, the question of pre-plant applications of nitrogen to alfalfa may still remain open.
2. Phosphorus deficiencies do restrict yields of alfalfa grown under irrigation where soil test values (phosphorus) are in the very low range. The restriction of yields by phosphorus is particularly severe where the A horizon (surface soil) has been removed by levelling operations.
3. The experiments reported here provided valuable information on response of alfalfa to phosphorus for soils testing in the very low range. However, no information was obtained which will be of value in refining soil test benchmarks. Resources do not allow the type of experiment conducted in 1969 to be repeated over a large number of sites. A more extensive approach, with a limited number of rates over a large number of sites, combined with the intensive approach used in 1969, should provide the required answers.

4. SULFUR REQUIREMENTS OF SELECTED CROPS

4.1 Field scale trials

4.1.1 A comparison of ammonium sulphate and ammonium nitrate

Five trials (nitrogen-sulfur trials) were laid down in which ammonium sulphate (21-0-0) and ammonium nitrate (34-0-0) were compared at three rates (20, 40 and 60 lb N/acre). Three of the trials were with wheat and one each with barley and rapeseed. A standard strip test formed the experimental design, with 10 sites (replicates) selected for soil sampling and yield measurements. The two fertilizers at the same rate of nitrogen were placed adjacent to one another. The fertilizers were broadcast prior to seeding with a trailer-mounted Cominco 70 attachment. Phosphorus was applied at the soil test recommended rate to the entire plot area.

The results (Table 16, Part A) show strong response to nitrogen for barley and rapeseed. The wheat plot (Warnock) where the soil test level was low also responded to nitrogen. The yields reported for the 20 lb N/acre rate for rapeseed are questionable. Due to a heavy wild oat infestation the plot was sprayed with Carbyne, but the strips on which the 20 lb N/acre rate was placed were inadvertently omitted.

The yields for the two sources of nitrogen, one sulfur-bearing and one not, were very similar at a given rate of nitrogen. From the limited amount of data reported here, it would be concluded that sulfur deficiencies did not limit the yields of wheat, barley or rapeseed on the plots tested.

Table 16. Response of selected crops to nitrogen, potassium and sulfur

A. NITROGEN-SULFUR TRIALS

				Yield Increase						
			Check* Yield	20 lb N/acre as		40 lb N/acre as		60 lb N/acre as		Nitrate Nitrogen lb/ac to 24"
Farmer	Soil	Crop	bu/acre	34-0-0	21-0-0**	34-0-0	21-0-0	34-0-0	21-0-0	Spring
Gordon	Ti:c	Barley	19.5	18.4	13.9	25.3	24.8	26.8	24.8	23
Rediger	Cr:vl	Rapeseed	17.2	-1.3	-1.5	4.0	4.9	8.0	9.0	44
Romaniuk	Sy:vl	Wheat	22.4	1.8	3.5	7.3	3.2	3.9	5.4	226
E. Stafford	Sy:vl	Wheat	38.3	-6.3	-3.9	2.5	0.8	3.6	-1.7	49
Warnock	Sy:vl	Wheat	8.9	6.7	6.6	9.6	7.4	9.5	11.9	24

*Phosphorus was applied to entire plot area at soil test recommended rate.
**21-0-0 contains 24% S.

B. POTASSIUM-SULFUR TRIALS

				Yield Increase						
			Check* Yield	30 lb K_2O/acre as		60 lb K_2O/acre as		90 lb K_2O/acre as		Available K lb/ac to 6"
Farmer	Soil	Crop	bu/acre	0-0-50**	0-0-60	0-0-50	0-0-60	0-0-50	0-0-60	Spring
Rediger	Cr:vl	Rapeseed	25.3	-1.1	-0.1	0.0	-0.3	1.5	0.8	89
Ewanus	Sy:vl	July-cut Alfalfa	0.86	0.12	0.07	0.15	0.05	0.15	0.01	310
		Sept-cut Alfalfa	0.33	0.08	0.06	0.20	0.01	0.15	0.01	

*Alfalfa yields in tons/acre. Phosphorus was applied to the entire plot area at the soil test recommended rate.

**0-0-50 contains 17.6% S.

4.1.2 A comparison of potassium sulfate and potassium chloride

In the second part of the sulfur work (potassium-sulfur trials), two trials were laid down in which potassium sulphate (0-0-50) and potassium chloride (0-0-60) were compared at three rates (30, 60 and 90 lb K_2O/acre). One trial was with rapeseed and one with alfalfa as the test crop. The experimental designs and methods were similar to that reported above for the nitrogen-sulfur experiments.

The results (Table 16, Part B), show no consistent response to potassium for either rapeseed or alfalfa. Response would have been expected on the rapeseed with a soil test level of 89 lb K/acre. In view of the observations noted previously (see Section 1.2), it appears as though the relationship with regard to soil test levels of K and response to added K is not simple for rapeseed. Further work is required to correlate soil test levels for potassium with crop response.

Sulfur response was not recorded for rapeseed, but some small response to sulfur was evident for alfalfa. The alfalfa site has been permanently staked to follow residual response. The small responses at the alfalfa site were not unexpected. The site was extremely dry (10 inches of moist soil) at the time of fertilization and just over one inch of rain was recorded up until July 1. Therefore, it is unlikely that the applied nutrients were moved into the rooting zone until late in the growing season. Yield measurements in subsequent years may show additional responses to the sulfur applied in 1969.

4.2 Rod-row experiments with S^{35} (by J.R. Bettany)

It has been well established that a great number of Western Canadian soils are deficient in plant-available sulphur. Crop responses to sulphur application have been reported for all three Prairie Provinces and British Columbia (2). The majority of these reports show that sulphur deficiency is confined mainly to the Grey Wooded soil zone and to certain light-textured soils low in organic matter occurring in Manitoba (1, 2, 6).

Within the Province of Saskatchewan, the sulphur-deficient soils occur mainly in the northern agricultural areas located in the Grey Wooded soil zone, which occupies some 3½ million farmed acres. Although the extent of the sulphur-deficient areas has not been accurately determined, there is evidence that S-deficiency is quite widespread (6).

The purpose of the preliminary sulphur studies was to determine how the plant availability of soil sulphur differed among selected soils occurring within the Grey Wooded soil zone. To achieve this goal, determination of sulphur availability indices ('A' values), using S^{35} labelled gypsum ($CaSO_4 . 2H_2O$), was considered as a reasonable approach. Difficulties of determination of total S in plant material, and S^{35} counting techniques were encountered when certain published methods were used. Hence, a reliable methodology was devised based on modification of those published methods which were considered most applicable to an automated procedure. An account of the methods used appears later in this report.

Experimental Sites

Analysis of the CaH_2PO_4 (500 ppm) extracts of a number of routine farm samples from the Grey Wooded soil zone indicated considerably less than 5 ppm sulphate-S in the surface 6 inches and were considered as sulphur-deficient soils. On the basis of these results and the corresponding farmer cooperation, three sites were chosen for this experiment located on the following soil associations, a Loon River loam, a Carrot River sandy loam and a Shellbrook sandy loam. Four treatments were used, 0, 15, 30 and 45 lb S/acre, on two crops, wheat and rape. The experimental design was a split plot of four replicates. Sulphur was applied with the seed as precipitated calcium sulphate dihydrate (gypsum) in six rows (7" spacing) of length 18 feet. On the 30 lb S/acre treatment S^{35}, labelled gypsum was used on rows 2 and 5. At each site, nitrogen was added as surface dressing of NH_4NO_3 to soil test recommendations. Phosphorus was added with the seed in the form of 15-60-0, again to soil test recommendations.

Harvest yields of the two crops were taken where possible and seed samples from the S^{35}-labelled rows were analyzed for total S and radioactivity.

Methods of Analysis

(a) Digestion

The digestion procedure used was essentially a modification of that described by Blancher et al (3) "1 g samples of plant material are weighed into 50 ml graduated cylinders and 3 ml of concentrated HNO_3 added. The acid is allowed to contact the plant material overnight before the cylinders are heated on a digestion block at 150°C for one hour. Two ml of 70% perchloric acid is then added and the temperature of the block increased to 235°C for a period of 2 hours. The block is then allowed to cool to 150°C and 1 ml of concentrated HCl added to the samples. The block is maintained at 150°C for 20 minutes, after which the tubes are removed and allowed to cool before being made up to 50 ml volume with deionized water.

(b) Total S Determination

Numerous methods are available for total S determination of plant material. Many of these methods are not suited to a rapid automated procedure and suffer from inherent inaccuracies. A review of methodology will not be attempted in this report, but it should be mentioned that a number of methods were applied and found unsuitable.

A turbidimetric procedure proved to be the most satisfactory since it was applicable to rapid analysis using the Technicon Auto-Analyzer. The method described below does not suffer from the "base-line drift" problem caused by flow cell coating by $BaSO_4$, and has a very high level of reproducibility.

(1) Reagents

Barium chloride reagent: 20 g of $BaCl_2$ (turbidimetric grade) and 5 g P.V.A. (polyvinyl alcohol) is added to 900 ml water containing 60 ml 1 N HCl. The mixture is heated and stirred until all material dissolves. The solution is then allowed to cool to room temperature and diluted to 1 litre.

Wash Solution (buffered E.D.T.A.)

6.75 g NH_4Cl, 40 g tetrasodium E.D.T.A. is dissolved in 800 ml deionized water, 57 ml of concentrated NH_4OH is added and the solution made to 1 litre with water. The pH of the solution is then adjusted to 10.10.

(2) Procedure

The plant digests (1 g plant material in 50 ml acidic solution) are diluted to fall within the range 5-35 ppm S (usually a further 1:20 dilution). This operation is best performed using an autodiluter, the diluted sample being made directly into the sample cups of the AutoAnalyzer.

A standard curve is prepared from 1,000 ppm S stock solution of an aqueous solution of potassium sulphate. The circuit used allows a sample rate of 30 per hour and utilizes a 50 mm flow cell (4).

S^{35} Counting Procedure

Liquid scintillation counting techniques have been shown to be more successful for determining the radioactivity of weak B^-emitters (7). Many different liquid scintillants have been proposed that are suitable for S^{35}-labelled materials. However, various disadvantages are associated with a number of these scintillation liquids. Strongly acidic aqueous solutions have strong quenching ability and also phase separation is evident in some scintillation liquids. Recently, Triton X-100 scintillant has been suggested for C^{14}-labelled materials (5). A modification of this procedure was adopted for this experiment.

Preparation of Triton X-100 Scintillant

0.4% PPO and 0.01% POPOP was dissolved in 600 ml of Toluene (spectro photometric grade), 300 ml of Triton X-100 was added to the solution and mixed. The resulting scintillant was placed in an automatic dispenser calibrated to deliver 15 ml portion of scintillant.

Counting Method

Exactly 1 ml of the diluted plant digest was added to 15 ml of scintillant in a counting vial and the solutions shaken briefly. A "Hamilton" 1 ml gas-tight syringe with Chaney adaptor was found most successful for transferring the 1 ml of acid digest (reproducibility of 0.01%). A Picker Nuclear Liquid Scintillation Counter was used for the sample counting. Quench correction for the samples was obtained using the external standard channels ratio method.

Results

Harvest yield data from this experiment were inconsistent and could not be statistically analysed. Poor germination of the rape was observed on all three sites. The available seeding equipment was found to have no provision for rapeseed, with the result that the rapeseed had to be placed on the V-belts with the fertilizer. Lack of depth control and poor seed distribution could explain the poor germination of the rape. In addition, heavy rain followed the seeding operation at the Loon River site, and the resulting surface crust prevented even germination of both wheat and rape.

However, the primary object of this experiment was to determine "A" values of the three soils and this could be accomplished without the need for yield data. The table below indicates the sulphur availability indices of the three soil associations.

Soil Association	S availability indices* (mean values) Rape	Wheat
Loon River	20.7	7.1
Carrot River	24.4	27.8
Shellbrook	10.8	-

*calculated from the equation:

$$A \text{ value} = \left(\frac{\text{Total } S^{32} \text{ (plant)}}{S^{35}\text{(plant)} \times \frac{S^{32} \text{ (fert)}}{S^{35} \text{ (fert)}}} - 1 \right) \times \text{Rate of Fertilizer}$$

Since the fertilizer rate for the three sites was the same (30 lb S/acre), the rate factor was omitted.

It can be seen from the above data that the "A" values differ considerably for the three soils, although CaH_2PO_4 (500 ppm) extracts of these soils indicated no marked differences in the amount of extractable sulphur, i.e. all results showed <4 ppm sulphates.

Before any definite conclusions may be drawn from these results, further studies are proposed utilizing the controlled conditions of the growth chamber.

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7. Wang, C.H. and Willis, D.L. Radiotracer Methodology in Biological Science. Publishers Prentice-Hall, Inc., New Jersey, 1965.

Appendix A Legal locations and rainfall records of all experimental sites.

Farmer	Legal Location	Rainfall Records (in.) May	June	July	Aug. 1-15	After Aug.15	Total to Aug.15
		Nitrogen Trials on Stubble					
Ayres	SE 26-37-6-W3	.73	1.71	3.32	.32	-	6.08
Bruce, B.	SE 2-19-26-W2	.85	1.70	3.55	-	-	6.10
Bruce, R.	S½ 18-19-25-W2	-	-	-	-	-	-
Coolidge	NW 20-49-25-W3	1.54	.72	2.93	.76	-	5.95
Froh	NE 35-7-19-W2	.50	3.40	5.95	-	-	9.85
Good	SW 7-11-10-W2	.25	.10	4.43	.24	.35	5.02
Hamilton	NE 19-33-17-W3	.82	.40	2.77	.60	-	4.59
Herndier	NE 5-19A-9-W2	.48	2.33	2.18	.58	.20	5.57
Kowalenko	SW 17-38-11-W3	2.16	.70	3.88	.41	-	7.15
Latrace	2-34-11-W3	2.34	.49	3.04	.53	-	6.40
Longmire	NW 6-30-21-W3	.07	1.24	2.55	.71	-	4.57
Raven	SW 13-37-10-W2	.45	1.13	4.07	.25	1.48	5.90
Turvey	SE 18-50-25-W3	2.01	.82	3.71	1.32	.05	7.86
Wallace	NE 20-39-24-W3	.28	.59	1.77	.22	-	2.86
Wallin	SW 31-33-9-W3	1.40	1.50	3.31	1.60	.74	7.81
		Potassium Trials					
Arnold	SE 30-53-13-W2	-	-	-	-	-	-
Bashforth	NE 24-35-8-W2	.21	1.06	3.91	.65	-	5.83
Cherepuschak	SW 11-51-12-W2	.27	.65	3.09	.43	.45	4.44
Ewanus	SW 16-49-17-W2	.57	.82	3.13	1.08	-	5.60
Gawyuk	SE 9-51-12-W2	.48	.69	2.90	.28	-	4.35
Kozun, Ernie	SE 27-49-12-W2	.45	.71	3.44	.90	3.18	5.50
Kozun, Eugene	SW 34-49-11-W2	.17	.98	4.31	-	1.00	5.46
Kozun, Nick	SE 19-50-11-W2	.17	.98	4.31	-	1.00	5.46
Skogsrud	NW 9-40-15-W2	.53	.95	5.63	1.77	.36	8.88
Stafford, L.	SW 9-49-16-W2	.36	1.06	3.57	1.20	.71	6.19
		Polyphosphate Trials					
Bellamy	NE 24-46A-25-W2	.81	.71	2.21	-	.60	3.73
Jensen	SE 3-30-13-W3	1.35	-	.30	-	-	1.65
Popoff	SE 6-36-3-W3	1.58	1.17	2.20	.61	-	5.56
Roth I	SE 35-42-4-W3	.58	.67	2.86	-	-	4.11
Roth II	NW 36-42-4-W3	.58	.67	2.86	-	-	4.11
		Small Plots, 1969					
Minky	SW 4-38-10-W2	.25	1.10	4.70	-	.80	6.05
Stevenson	NW 3-37-4-W3	-	-	-	-	-	-
Rediger	SE 12-49-12-W2	.50	.56	4.22	.50	-	5.78
Ewanus	SE 24-48-18-W2	.57	.82	3.13	1.08	-	5.60

Appendix A Legal locations and rainfall records of all experimental sites

Farmer	Legal Location	May	June	July	Aug. 1-15	After Aug.15	Total to Aug. 15
		Rainfall Records (in.)					
		Nitrogen-Sulfur Trials					
Gordon	NE 10-50-8-W2	-	-	-	-	-	5.50
Rediger	SW 11-49-12-W2	.50	.56	4.22	.50	-	5.78
Romaniuk	SW 36-48-16-W2	.72	.85	2.86	1.25	-	5.68
Stafford, E.	NE 25-48-17-W2	.55	.89	3.46	1.90	.50	6.80
Warnock	NE 28-50-13-W2	.33	.75	3.67	.80	3.96	5.50
		Potassium-Sulfur Trials					
Ewanus	SE 17-49-17-W2	.57	.82	3.13	1.08	-	5.60
Rediger	SE 12-49-12-W2	.50	.56	4.22	.50	-	5.78
		V.L.A. Trials					
Baker Hayward	SE 22-8-30-W2	-	1.90	3.57	-	-	5.47
Cox Ford	NW 28-37-23-W2	.76	.64	3.54	.01	3.58	4.95
Zinkhan Denis	SW 34-11-5-W3	.55	1.23	3.96	.20	-	5.94
Kendel Tosh	SE 22-14-3-W2	.31	2.95	3.28	.29	.60	6.83
King Craig	SE 5-19-26-W2	.50	1.80	3.60	-	-	5.90
Laing Boechler	SE 15-50-8-W3	-	.50	3.85	-	.10	4.35
Mackay Stadnick	NW 31-6-18-W2	-	-	-	-	-	-
McDonald Yakubowich	NE 24-25-6-W2	.75	1.50	3.08	2.67	.90	8.00
McLeod Beddome	32-46-26-W2	.92	1.26	3.37	-	-	5.55
Murch Adair	NW 36-30-11-W3	.80	-	2.36	.20	-	3.36
Peace Porter	SE 6-45-21-W2	-	.69	4.99	-	-	5.68
Puckey Nowosad	NE 32-36-27-W2	.50	.60	2.65	.50	.20	4.25

ppendix A Legal locations and rainfall records of all experimental sites.

rmer	Legal Location	May	June	July	Aug. 1-15	After Aug.15	Total to Aug. 15
		Rainfall Records (in.)					
			V.L.A. Trials (Cont'd.)				
lkeld ith	SW 33-26-3-2	.45	1.86	2.96	1.73	.72	7.00
erwin lvig	SE 32-9-18-3	.70	2.90	6.15	-	-	9.75
.kora lovany	SW 14-19-2-2	.25	2.08	2.52	1.10	.90	5.95
.mpson nti	NW 34-38-25-3	.35	.20	1.05	-	-	1.60
eabner ckham	NE 29-36-26-3	-	-	-	-	-	5.60
eenson olek	SW 9-44-17-3	.32	.11	2.23	.20	-	2.86
ewart Leod	SW 14-8-3-2	-	1.45	9.86	1.28	.04	12.59
lwood .ndstrom	SE 22-35-13-2	.80	.95	9.00	2.50	-	13.25
ite oper	SE 4-44-14-2	.20	1.18	3.54	.58	-	5.50
.nkhan rrie	NW 12-24-23-2	-	1.36	2.41	.23	1.04	4.00

Appendix B Soil test data for all experimental sites

Farmer	Depth	Nitrate-Nitrogen lb/acre Fall	Spring	Available P lb/acre Fall	Spring	Available K lb/acre Fall	Spring
		Nitrogen Trials on Stubble					
Ayres	0- 6	-	8	-	12	-	633
	6-12	-	4	-	6	-	219
	12-24	-	6	-	9	-	337
Bruce, B.	0- 6	-	14	-	29	-	783
	6-12	-	10	-	13	-	548
	12-24	-	17	-	18	-	859
Bruce, R.	0- 6	-	30	-	26	-	725
	6-12	-	13	-	10	-	418
	12-24	-	12	-	15	-	643
Coolidge	0- 6	14	14	10	18	424	421
	6-12	7	8	9	9	220	316
	12-24	6	9	12	12	480	597
Froh	0- 6	-	17	-	19	-	680
	6-12	-	13	-	10	-	348
	12-24	-	22	-	17	-	470
Good	0- 6	-	15	-	29	-	653
	6-12	-	17	-	15	-	470
	12-24	-	46	-	18	-	646
Greer	0- 6	-	7	-	18	-	625
	6-12	-	5	-	12	-	396
	12-24	-	4	-	20	-	716
Hamilton	0- 6	-	8	-	22	-	452
	6-12	-	4	-	13	-	297
	12-24	-	4	-	18	-	636
Herndier	0- 6	-	17	-	34	-	655
	6-12	-	8	-	14	-	394
	12-24	-	7	-	19	-	637
Hult	0- 6	-	15	-	15	-	358
	6-12	-	7	-	15	-	235
	12-24	-	7	-	24	-	436
Kowalenko	0- 6	-	7	-	23	-	594
	6-12	-	5	-	14	-	411
	12-24	-	6	-	19	-	413
Latrace	0- 6	42	8	74	23	900+	665
	6-12	12	5	17	11	764	332
	12-24	44	7	20	16	1280	427
Longmire (7 sites)	0- 6	-	15	-	25	-	584
	6-12	-	8	-	12	-	360
	12-24	-	13	-	19	-	746
Raven (5 sites)	0- 6	-	13	-	23	-	260
	6-12	-	6	-	9	-	234
	12-24	-	10	-	19	-	346

Appendix B Soil test data for all experimental sites (cont'd.)

Farmer	Depth	Nitrate-Nitrogen lb/acre Fall	Nitrate-Nitrogen lb/acre Spring	Available P lb/acre Fall	Available P lb/acre Spring	Available K lb/acre Fall	Available K lb/acre Spring
		Nitrogen Trials on Stubble					
Wallace	0- 6	-	12	-	17	-	472
	6-12	-	8	-	9	-	243
	12-24	-	13	-	16	-	495
Wallin	0- 6	-	30	-	23	-	278
	6-12	-	16	-	14	-	176
	12-24	-	16	-	22	-	354
Turvey (5 sites)	0- 6	10	10	19	10	616	394
	6-12	4	6	10	6	456	276
	12-24	6	6	16	12	720	600
		Polyphosphate Trials					
Bellamy	0- 6	-	30	-	18	-	540
	6-12	-	13	-	9	-	356
	12-24	-	27	-	17	-	387
Jensen	0- 6	-	19	-	20	-	668
	6-12	-	19	-	12	-	410
	12-24	-	26	-	20	-	669
Popoff	0- 6	-	25	-	23	-	784
	6-12	-	15	-	9	-	335
	12-24	-	33	-	13	-	542
Roth (Barley)	0- 6	-	37	-	24	-	690
	6-12	-	16	-	10	-	385
	12-24	-	30	-	8	-	634
Roth (Wheat)	0- 6	-	38	-	14	-	610
	6-12	-	12	-	5	-	275
	12-24	-	21	-	7	-	584
		Potassium Trials					
Arnold	0- 6	30	93	9	17	28	85
	6-12	16	28	6	7	16	66
	12-24	24	23	8	9	32	84
Bashforth	0- 6	-	45	-	10	-	207
	6-12	-	20	-	4	-	233
	12-24	-	24	-	11	-	358
Cherepuschak	0- 6	42	103	11	24	40	234
	6-12	12	48	6	19	20	180
	12-24	18 (7 sites)	36	12	7	56	129
Ewanus	0- 6	13	27	12	21	188	420
	6-12	14	13	5	12	92	265
	12-24	22	19	10	18	192	530
Gawyuk	0- 6	11	54	12	10	48	60
	6-12	2	15	6	6	20	48
	12-24	4	23	12	10	72	95

Appendix B   Soil test data for all experimental sites (cont'd.)

Farmer	Depth	Nitrate-Nitrogen lb/acre Fall	Spring	Available P lb/acre Fall	Spring	Available K lb/acre Fall	Spring
			Potassium Trials				
Kozun, Ernie	0- 6	11	12	15	13	76	79
	6-12	4	4	12	6	56	65
	12-24	4	6	16	10	136	130
Kozun, Eugene	0- 6	10	32	9	6	64	51
	6-12	4	15	3	3	44	50
	12-24	6	29	5	5	80	92
Kozun, Nick	0- 6	56	88	10	11	64	50
	6-12	29	26	6	6	44	38
	12-24	36	33 (9 sites)	6	8	64	67
Skogsrud	0- 6	-	31	-	22	-	237
	6-12	-	16	-	10	-	138
	12-24	-	28	-	12	-	234
Stafford, Ken	0- 6	11	22	7	16	44	74
	6-12	10	9	6	8	44	67
	12-24	18	15	10	15	80	147
Stafford, Les	0- 6	16	27	20	20	40	68
	6-12	10	9	13	10	24	52
	12-24	14	14	20	12	56	135
			Nitrogen-Sulfur Trials				
Gordon	0- 6	-	16	-	53	-	280
	6-12	-	3	-	14	-	231
	12-24	-	6	-	19	-	587
Romaniuk	0- 6	8	51	28	24	304	158
	6-12	2	53	18	9	212	102
	12-24	2	121	30	15	424	306
Stafford, Earl	0- 6	14	23	21	31	212	224
	6-12	7	9	16	16	152	116
	12-24	8	17	26	23	296	252
Warnock	0- 6	8	8	46	24	356	214
	6-12	4	6	32	15	212	143
	12-24	8	10	40	23	400	229
Rediger	0- 6	-	24	-	12	-	108
	6-12	-	8	-	5	-	68
	12-24	-	12	-	6	-	119
			Potassium-Sulfur Trials				
Rediger	0- 6	27	72	19	29	84	89
	6-12	10	21	5	8	48	59
	12-24	58	32	4	8	104	85
Ewanus	0- 6	-	8	-	25	-	310
	6-12	-	4	-	18	-	241
	12-24	-	6	-	26	-	571

Appendix C Yield results - V.L.A. co-operative project.

Yields in bushels per acre; fertilizer rates in pounds per acre

Advisor Farmer Crop Area Soil Type	Treatment	Yield
Baker (Hayward)	Average Check	23.0
Wheat	11-48-0 @ 43	25.9
Assiniboia	23-23-0 @ 76	28.0
Sc:c-Hr:cl	11-48-0 @ 43 plus 33.5-0-0 @ 120	33.6
Cox (Ford)	Average Check	13.6
Wheat	11-48-0 @ 41	16.8
Humboldt	23-23-0 @ 91	27.5
B:l	11-48-0 @ 41 plus 34-0-0 @ 75	23.2
Draftenza (Denis)	Check	30.2
Durum	11-48-0 @ 43	33.7
Gravelbourg	23-23-0 @ 87	46.5
Fx:sicl		
Kendel (Tosh)	Average Check	12.5
Flax	11-48-0 @ 40	16.2
Langbank	23-23-0 @ 89	17.0
O:l	11-48-0 @ 40 plus 33.5-0-0 @ 130	17.9
	11-48-0 @ 50 plus 33.5-0-0 @ 100	18.4
King (Craig)	Average Check	23.1
Durum	11-48-0 @ 40	40.2
Tuxford	23-23-0 @ 90	32.9
Tu:c	11-48-0 @ 40 plus 46-0-0 @ 100	36.3
	11-48-0 @ 60 plus 46-0-0 @ 75	40.6
	46-0-0 @ 30	26.5
Laing (Boechler)	Average Check	14.9
Barley	11-48-0 @ 64	18.7
Spiritwood	23-23-0 @ 83	22.8
Wh-P:l	11-48-0 @ 65 plus 46-0-0 @ 80	30.7
	11-48-0 @ 65 plus 46-0-0 @ 120	32.3
MacKay (Stadnick)	Average Check	16.7
Wheat	11-48-0 @ 40	28.4
Radville	23-23-0 @ 87	26.0
W-Es:cl	11-48-0 @ 40 plus 33.5-0-0 @ 120	17.9
McDonald (Yakubowich)	Average Check	36.1
Oats	11-48-0 @ 84	47.3
Yorkton	23-23-0 @ 75	59.1
Me:fl	11-48-0 @ 115 plus 33.5-0-0 @ 268	70.6

Advisor Farmer Crop Area	Treatment	Yield
McLeod(Beddome)	Average Check	17.5
Wheat	11-48-0 @ 40	15.3
Prince Albert	23-23-0 @ 83	21.6
Sb:vl	11-48-0 @ 40 plus 46-0-0 @ 95	15.2
	11-48-0 @ 63 plus 46-0-0 @ 76	20.2
Murch (Adair)	Average Check	27.9
Barley	11-48-0 @ 53	33.6
Milden	23-23-0 @ 58	27.3
E:c	11-48-0 @ 53 plus 34-0-0 @ 134	38.3
Peace (Porter)	Average Check	30.7
Barley	11-55-0 @ 42	40.9
Kinistino	23-23-0 @ 91	42.9
M:Sicl	11-55-0 @ 42 plus 34-0-0 @ 130	43.8
Puckey (Nowosad)	Average Check	18.9
Wheat	11-48-0 @ 45	24.7
Meacham	23-23-0 @ 80	22.8
E:Sicl	11-48-0 @ 45 plus 34-0-0 @ 76	22.3
	11-48-0 @ 45 plus 34-0-0 @ 111	20.7
Salkeld(Keith)	Average Check	31.5
Wheat	11-48-0 @ 40	34.2
Yorkton	23-23-0 @ 90	38.6
Ca:sicl	11-48-0 @ 40 plus 33.5-0-0 @ 65	31.2
	11-48-0 @ 40 plus 33.5-0-0 @130	34.1
Sherwin(Selvig)	Check	36.4
Barley	11-48-0 @ 38	44.4
Shaunavon	23-23-0 @ 76	35.1
Cy:cl	11-48-0 @ 38 plus 34-0-0 @ 75	42.0
	11-48-0 @ 38 plus 34-0-0 @ 110	43.5
Sikora(Kulovany)	Average Check	30.9
Oats	11-48-0 @ 40	31.0
Esterhazy	23-23-0 @ 87	33.3
O:l	11-48-0 @ 40 plus 33.5-0-0 @ 120	35.3

Appendix C Yield results - V.L.A. co-operative project.

Yield in bushels per acre; fertilizer rates in pounds per acre

Advisor Farmer Crop Area Soil Type	Treatment	Yield
Simpson (Zunti)	Average Check	20.8
Wheat	11-48-0 @ 42	25.6
Unity	23-23-0 @ 90	30.6
W:cl	11-48-0 @ 42 plus 34-0-0 @ 72	31.4
Steabner (Peckham)	Average Check	25.4
Wheat	11-48-0 @ 39	28.6
Hearts Hill	23-23-0 @ 85	28.5
E:cl	11-48-0 @ 39 plus 34-0-0 @ 60	30.2
	11-48-0 @ 39 plus 34-0-0 @ 100	30.0
Steenson (Frolek)	Average Check	18.7
Wheat	11-48-0 @ 38	23.0
Battleford	23-23-0 @ 87	27.7
Me:fl	11-48-0 @ 50 plus 33.5-0-0 @ 75	25.3
	11-48-0 @ 50 plus 33.5-0-0 @120	23.4
Stewart (McLeod)	Average Check	24.6
Barley	11-55-0 @ 38	27.9
Carlyle	23-23-0 @ 90	33.7
Cd:sil	11-55-0 @ 38 plus 34-0-0 @ 120	45.0
Welwood(Lindstrom)	Check	22.7
Wheat	11-48-0 @ 48	20.9
Wadena	23-23-0 @ 73	26.8
Y:l	11-48-0 @ 48 plus 33.5-0-0 @ 115	26.2
Zinkhan (Currie)	Check	15.6
Wheat	11-48-0 @ 58	16.7
Strasbourg	23-23-0 @ 94	19.8
W:l	11-48-0 @ 58 plus 34-0-0 @ 110	24.5
White (Hooper)	Average Check	13.3
Wheat	11-48-0 @ 35	13.1
Tisdale	23-23-0 @ 75	17.5
Ti: sicl	11-48-0 @ 42 plus 34-0-0 @ 113	20.3
	11-48-0 @ 58 plus 34-0-0 @ 128	26.1

Appendix B Soil test data for all experimental sites (cont'd.)

Farmer	Depth	Nitrate-Nitrogen lb/acre Fall	Spring	Available P lb/acre Fall	Spring	Available K lb/acre Fall	Spring
			N15 Trial				
Minky	0- 6	-	8	-	32	-	252
	6-12	-	5	-	20	-	308
	12-24	-	9	-	30	-	418
			Polyphosphate (P32) Trials				
Stevenson (Orthic)	0- 6	-	28	-	17	-	530
	6-12	-	24	-	10	-	388
	12-24	-	56	-	13	-	716
	24-48	-	128	-	44	-	1628
Stevenson (Gleysol)	0- 6	-	42	-	34	-	829
	6-12	-	22	-	11	-	503
	12-24	-	48	-	16	-	900
	24-48	-	193	-	31	-	1211
Rediger	0- 6	-	91	-	22	-	85
	6-12	-	16	-	8	-	50
	12-24	-	26	-	10	-	80
	24-48	-	52	-	18	-	144
			V.L.A. Trials				
Baker Hayward	0- 6	3	-	23	-	672	-
	6-12	3	-	13	-	444	-
	12-24	16	-	18	-	792	-
Cox Ford	0- 6	11	18	16	26	456	504
	6-12	6	11	7	15	240	356
	12-24	6	10	8	12	480	448
Dennis Peach	0- 6	10	-	48	-	796	-
	6-12	6	-	16	-	284	-
	12-24	20	-	24	-	520	-
Draftenza Denis	0- 6	11	8	34	37	901	900+
	6-12	15	7	14	15	560	452
	12-24	12	14	22	26	928	720
Zinkham Currie	0- 6	2	10	42	38	864	840
	6-12	2	6	15	21	388	436
	12-24	2	18	22	24	680	680
Kendal Tosh	0- 6	8	14	22	30	588	368
	6-12	4	12	12	16	384	176
	12-24	4	20	14	22	672	344
King Craig	0- 6	9	11	18	36	620	604
	6-12	4	4	9	11	492	312
	12-24	6	6	14	12	896	568

Appendix B Soil test data for all experimental sites (cont'd.)

Farmer	Depth	Nitrate-Nitrogen lb/acre Fall	Spring	Available P lb/acre Fall	Spring	Available K lb/acre Fall	Spring
Laing Boechler	0- 6	2	22	24	35	128	96
	6-12	2	13	17	26	104	72
	12-24	2	16	22	52	200	128
McDonald Yakubowich	0- 6	19	32	17	20	268	200
	6-12	6	9	6	6	60	60
	12-24	14	12	8	10	160	224
MacKay Stadnick	0- 6	13	39	22	35	652	812
	6-12	1	14	13	10	388	196
	12-24	6	79	20	14	576	328
McLeod Beddome	0- 6	17	13	12	11	712	496
	6-12	6	9	7	7	352	264
	12-24	10	18	16	12	656	488
Morrow Young	0- 6	4	-	15	-	232	-
	6-12	2	-	9	-	184	-
	12-24	2	-	30	-	344	-
Murch Adair	0- 6	11	11	23	15	901	528
	6-12	2	3	10	8	272	200
	12-24	4	10	12	14	480	344
Peace Porter	0- 6	10	29	47	48	792	744
	6-12	2	6	30	17	444	404
	12-24	2	10	44	24	1016	744
Puckey Nowosad	0- 6	12	18	22	20	901	696
	6-12	6	2	12	9	592	472
	12-24	6	10	16	14	1040	880
Salkeld Keith	0- 6	9	24	35	34	901	704
	6-12	14	10	23	14	556	294
	12-24	14	70	20	16	784	432
Sherwin	0- 6	7	6	19	24	560	544
	6-12	4	7	10	10	348	232
	12-24	4	32	14	14	616	512
Sikora Kulovany	0- 6	8	13	25	25	288	276
	6-12	7	53	11	8	196	144
	12-24	14	8	10	12	344	312
Simpson	0- 6	7	6	20	32	744	824
	6-12	8	13	12	11	472	464
	12-24	8	14	14	18	824	824
Steabner Peckham	0- 6	8	12	30	24	744	560
	6-12	3	13	12	10	340	300
	12-24	30	22	14	20	936	440
Steenson Frolek	0- 6	7	8	12	13	320	257
	6-12	5	5	11	8	224	168
	12-24	12	8	16	14	424	288
White Hooper	0- 6	5	6	20	23	328	308
	6-12	2	4	13	11	300	240
	12-24	2	10	22	22	592	488
Stewart	0- 6	-	13	-	24	-	624
	6-12	-	7	-	10	-	232
	12-24	-	10	-	14	-	400
Welwood	0- 6	-	35	-	20	-	228
	6-12	-	18	-	13	-	216
	12-24	-	30	-	18	-	368

6. SELECTED REVIEW PAPERS

6.1 Potassium research in Saskatchewan[1] (by E.H. Halstead)

Of the 50 million acres of land in Saskatchewan which are considered to be in arable soil capability classes, it is estimated that between one-half and one million acres may respond to potash fertilization. Response to fertilizers containing potash is most likely to occur on sandy or peaty soils in the Gray-Black and Gray-Wooded Soil Zones. However, other light-textured soils, in addition to some of the high lime soils throughout the province, may also require potash.

Researchers in the province have been including potassium in some of their field experiments for a good number of years. At the Indian Head Experimental Farm, 20 pounds of KCl per acre has been applied with 40 pounds of 11-48-0 in an experiment over a period of 22 years. During this period, there has not been a significant yield response on wheat due to the inclusion of the potassium (Table 1).

Table 1. Comparison of 11-48-0 and 11-48-0 + KCl Fertilization in Southeastern Saskatchewan - Indian Head Farm, Average Data 1951-1955

District	11-48-0 (40 lb/A)	11-48-0 + KCl (40 lb/A) (20 lb/A)
Alameda*	33.7	32.4
Arcola*	30.0	28.3
Fleming**	29.5	30.8
Kelliher*	42.5	42.9
Strasbourg*	33.9	33.5
Wawota**	31.7	30.8
Yorkton*	36.6	37.4
Indian Head Farm***	39.7	39.6

*4-year average
**5-year average
***21-year average

[1] Paper presented to the annual meeting of the Western Section of the National Soil Fertility Committee, Edmonton, Alta., Feb. 13-14, 1969.

During the five-year period, 1951 to 1955, a series of rod-row tests were conducted in Southeastern Saskatchewan. KCl was applied at 20 pounds per acre alone and in combination with three rates of N and P_2O_5. The only response to potash was obtained at Kelliher where there was 20 pounds of KCl applied alone. When KCl was applied in combination with N and P_2O_5, there was no response to potassium. The average data comparing the 11-48-0 and the 11-48-0 plus KCl treatments are also shown in Table 1.

Experiments conducted in Northeastern Saskatchewan by the Melfort Station for the five-year period, 1951 to 1955, are summarized in Table 2. These data indicate small yield increases due to the inclusion of 20 pounds of KCl with 40 pounds of 11-48-0, as compared to 11-48-0 alone. A trend towards yield increases on the course-textured and the peaty surface soils is also indicated.

Table 2. Comparison of 11-48-0 and 11-48-0 + KCl Fertilization in Northeastern Saskatchewan - Melfort Farm, Average Data 1951-1955

Soil	11-48-0 (40 lb/A)	11-48-0 (40 lb/A) + KCl (20 lb/A)
Me:FL	41.2	42.7
B:CL	25.1	26.5
Sb:FL	41.1	41.5
Pw:L	33.0	34.6
B:L	28.5	28.5
Ti:C	29.7	38.7
Wf:VL	32.7	34.5
Wh:L	36.7	36.0
Ti:C	35.5	40.2
P:L	39.8	44.9
Ga:L	29.3	29.0
Bd:L	29.3	30.7

Experiments conducted in Northwestern Saskatchewan by the Scott Experimental Farm from 1949 to 1955 also show trends toward slight yield increases due to the inclusion of potash (Table 3). Very little research on the nature of the responses of cereal crops to potash fertilization has been carried out in the Southwestern section of the province.

Table 3. Comparison of 16-20-0 and 16-20-0 + K_2O Fertilization in Northwestern Saskatchewan - Scott Experimental Farm, 1949-1955

Soil	Number of Years	16-20-0 (100 lb/A)	16-20-0 + K_2O (100 lb/A) (20 lb/A)
Ln:L	6	28.3	27.4
Do:L	6	28.0	29.1
Wv:Wh:L	7	32.3	31.8
Gb:GL	5	38.7	39.9
Bd:L	1	20.2	24.4

The Department of Soil Science at the University of Saskatchewan, Saskatoon carried out field investigations on potassium response from 1960 to 1963. In a majority of the experiments 0-0-60 was mixed with 11-48-0 to produce a fertilizer with an analysis of 6-26-26. The fertilizers 6-26-26 and 11-48-0 were then compared at rates of 20 pounds of P_2O_5 per acre. In a majority of treatments, the potash and phosphate were placed in direct contact with the seed. An unfertilized check strip was left adjacent to each fertilizer strip. The soils used in these experiments were either light-textured Gray-Black or Gray Wooded soils, or soils which contained free lime to the surface. Levels of NH_4OAc extractable and hot 1N HNO_3 potassium were determined on samples taken from the plot area.

On Black Chernozemic soils (Table 4), 6-26-26 did not perform as well as 11-48-0 when applied at the same rate of P_2O_5. In 1962, on both the Canora and Yorkton soils, the yield increase for 11-48-0 was significantly greater than for 6-26-26. Similar comparative results were obtained for light-textured Gray-Black soils (Table 5).

Table 4. Comparison of 11-48-0 and 6-26-26
Black Chernozemic Soils
(20 lb P_2O_5/A)

Year	Soil	No. of Plots	Check Yield	Yield Increase 11-48-0	6-26-26	L.S.D.	NH_4OAc-K (lb/A)
1960	Ca:L	75	29.1	5.4	5.2	N.S.	805
1961	Ca:L	30	24.5	7.1	7.6	N.S.	670
1962	Ca:L	40	34.9	7.3	3.7	3.2	830
1962	Y:L	20	25.0	4.3	1.5	2.2	600
Average			28.4	6.0	4.5	N.S.	

Table 5. Comparison of 11-48-0 and 6-26-26
Gray-Black Soils
(20 lb P_2O_5/A)

Year	Soil	No. of Plots	Check Yield	Yield Increase 11-48-0	6-26-26	L.S.D.	NH_4OAc-K (lb/A)
1960	Sb:FL	15	23.2	9.2	2.9	3.5	370
1960	Wf:FL	45	28.3	2.4	2.5	N.S.	510
1961	Wf:FL	30	10.6	1.5	-0.3	N.S.	450
1962	Wf:FL	30	24.9	3.2	3.8	N.S.	310
1960	Np:L	45	36.0	6.0	4.9	N.S.	350
1961	Np:L	20	17.2	1.7	1.9	N.S.	360
1962	Np:L	20	34.1	1.7	0.3	N.S.	300
Average			24.9	3.7	2.3	N.S.	

In particular, 6-26-26 placed with the seed was much inferior to 11-48-0 on the Shellbrook soil in 1960. There was no significant differences in yields between the two carriers on the White Fox and Nipawin soils.

The average yields obtained from plots laid down in 1961 and 1962 on the Carrot River, and in 1962 on the Weirdale Loam, indicate the need for supplemental potash (Table 6). On these soils, 6-26-26 out-performed 11-48-0. Both the Weirdale and Carrot River soils contain a significant proportion of shallow peaty areas. Visual response to potash was marked on these areas.

Table 6. Comparison of 11-48-0 and 6-26-26
Gray Wooded Soils
(20 lb P_2O_5/A)

Year	Soil	No. of Plots	Check Yield	Yield Increase 11-48-0	Yield Increase 6-26-26	Yield Increase L.S.D.	NH_4OAc-K (lb/A)
1960	PS	15	20.7	-0.2	-0.6	N.S.	510
1961	We:L	20	17.8	4.4	4.3	N.S.	1030
1962	We:L	20	39.5	4.6	10.1	3.2	450
1961	Cr:L	10	11.0	2.5	5.2	1.6	230
1962	Cr:L	20	16.6	8.6	16.6	4.1	-
Average			21.1	4.0	7.1	1.4	

Broadcast applications of 0-0-60 at 330 pounds per acre were applied on soils in Eastern and Northeastern Saskatchewan during the 1960 to 1963 period. The data presented in Table 7 show no increase in yield over 11-48-0 due to this treatment. However, unlike the seed-placed potash, there was no indication of a decrease in yield due to the broadcast application. This would suggest that the incorporation of KCl with 11-48-0 either caused a reduction in stand or interfered with the uptake of phosphorus. "A" value experiments conducted during the same period supported the suggestion that the inclusion of KCl in the phosphate carrier may depress the availability of the fertilizer phosphorus.

Prior to 1966, most of the potassium trials conducted in the province were set out on fields without any knowledge of the levels of available soil potassium. For this reason, the majority of trials ended up on soils with high levels of exchangeable potassium. As a result, there were few cases of response to potash recorded. With the opening of the Saskatchewan Soil Testing Laboratory in the fall of 1966, levels of NH_4OAc extractable potassium were made available for a large number of fields. This information was used in selecting sites for field investigations conducted in 1967 and 1968.

Table 7. Yields of Cereals With and Without Broadcast Application of 200 lb/A K_2O 1960-1963

Soil	11-48-0	11-48-0 + K_2O	L.S.D.
Y:L	13.9	13.3	N.S.
Ca:L	17.9	16.3	N.S.
Wf:FL	14.4	13.9	N.S.
Np:L	34.3	33.7	N.S.
Np:L	40.0	43.5	N.S.
Wf:L	21.8	21.8	N.S.
Average	23.7	23.8	N.S.

In 1967, fields were selected which had very low or low levels of NH_4OAc potassium from soil test reports. Trials which included applications of 10-30-10 and 0-0-60 were set out at 12 sites. In these trials, the rates of nitrogen and phosphate applied were based on soil test recommendations. The fertilizer 10-30-10 was applied at the same rate of P_2O_5 as 11-48-0. Where 0-0-60 was used, it was applied as a broadcast application at the rate of 60 pounds of K_2O per acre. The data obtained are presented in Tables 8, 9 and 10.

For barley, good yield increases due to the addition of potash were obtained on soils with low soil test levels of potassium. On the average, 11-48-0 applied with the seed, plus 0-0-60 broadcast were superior to the complete fertilizer 10-30-10 placed with the seed (Table 8). With barley, responses to potash were obtained on soils with relatively high levels of NH_4OAc potassium (Table 9). In comparison, wheat did not respond to the addition of potash on any of the three trials set out in 1967 (Table 10).

Table 8. Response of Barley to Potash Fertilization
1967 Data

Soil	Check Yield	Yield Increases* 11-48-0	10-30-10	11-48-0 + 0-0-60	Soil Test (lb/A)
Gb:LS	28.3	-0.8	14.4	10.1	48
Cr:VL	48.2	22.7	25.0	22.0	79
Cr:VL	42.4	13.0	8.4	16.0	75
Cr:VL	28.9	15.3	7.0	22.0	45
Cr:VL	25.3	3.7	5.3	6.6	57
Cr:VL	28.8	-1.8	11.2	10.3	36
Average	33.7	8.7	11.9	14.5	57

*N and P_2O_5 applied at soil test recommended rates

Table 9. Response of Barley to a Broadcast Application of 60 lb/A K_2O

1967 Data

Soil	Check Yield	Yield Increase* 11-48-0 + 33.5-0-0	11-48-0 + 33.5-0-0 + 0-0-60	Soil Test (lb/A)
Sb:FL	25.6	8.7	26.1	224
Cr:VL	26.2	3.1	17.9	49
Wf:VL	23.9	9.7	15.2	159
Average	25.2	7.2	19.7	144

*N and P_2O_5 applied at soil test recommended rates

Table 10. Response of Wheat to a Broadcast Application of 60 lb/A K_2O

1967 Data

Soil	Check Yield	11-48-0 + 33.5-0-0	11-48-0 + 33.5-0-0 + 0-0-60	Soil Test (lb/A)
Sb:FL	8.9	6.5	4.5	282
Sb:FL	23.9	7.6	4.6	323
Sb:FL	15.6	2.5	2.8	70
Average	16.1	5.5	4.0	225

*N and P_2O_5 applied at soil test recommended rates

In 1968, fields with low levels of potassium were again selected for field trials. In these experiments, nitrogen and phosphate were applied to the entire plot area at the soil test recommended rate, and 0-0-60 was broadcast prior to seeding at 100, 200 and 400 pounds per acre. Seven out of the nine trials carried out in 1968 were on the Carrot River soil. The other two trials were on the White Fox and Weirdale soils.

The yield results (Table 11) show that excellent responses to potassium were obtained in most of the trials. However, the results tend to follow two patterns of response. In five of the trials, the results follow an increasing increment type of curve. In the other four experiments, response to potassium either failed to occur or occurred only at the lower rate of potash application. As in 1967, barley responded better than wheat.

The levels of NH_4OAc and $NaHCO_3$ extractable potassium (Table 11) both appear to be successful tests for delineating areas of potassium deficiency. However, further research will be required to evaluate and refine current soil test benchmarks for all crops. In addition, research should be expanded to include more fields from soil associations such as: Sylvania, White Fox, Shellbrook, La Corne and some high lime soils. Residual response to broadcast applications of potash will have to be determined.

Table 11. Response of Barley, Wheat and Rapeseed to Potash Fertilization 1968 Data

			Yield Increase with Potash			Soil Test	
Soil	Crop	Yield*	60 lb	120 lb	240 lb	NH_4OAc	$NaHCO_3$
Cr:VL	Barley	10.9	27.0	37.6	46.8	67	47
Cr:VL	Barley	24.1	14.8	26.6	27.8	61	50
Cr:VL	Barley	44.7	18.6	13.5	9.1	89	90
Cr:VL	Barley	39.4	2.8	9.4	19.8	144	119
Wf:VL	Barley	44.9	17.6	5.3	5.1	172	200
Cr:VL	Wheat	5.4	9.5	12.8	15.0	71	79
Cr:VL	Wheat	35.8	7.6	7.5	2.4	104	88
We:CL	Wheat	45.5	0.0	-1.0	2.1	238	182
Cr:VL	Rapeseed	26.2	0.3	2.9	3.5	101	95

*Nitrogen and phosphorus were applied at soil test recommended rates

In 1968 the Saskatchewan Soil Testing Laboratory began analyzing all samples received for $NaHCO_3$ extractable potassium. This procedure replaced the NH_4OAc extract which had been used for the two previous years. Research conducted by the laboratory using 0.5 M $NaHCO_3$ showed that this extract, on the average, removed about two-thirds as much potassium as 1N NH_4OAc. A comparison of the two sets of benchmarks together with the average amount of potassium extracted for each soil test level is shown in Table 12. These data were obtained from soil test summaries. The plus sign (+) for the $NaHCO_3$ data indicates that the levels of potassium greater than 900 pounds per acre were all recorded as 901. These data again indicate that, on the average, 0.5M $NaHCO_3$ extracts approximately two-thirds as much potassium as 1N NH_4OAc.

Table 12. Comparison of NH_4OAc and $NaHCO_3$ Potassium in Saskatchewan Soils

Rating	NH_4OAc K	Av. Test	Sample No.	$NaHCO_3$ K	Av. Test	Sample No.	Ratio
VL	0- 90	71	30	0- 60	44	5	.62
L	91-180	131	53	61-120	99	17	.75
M	181-270	216	104	121-180	158	42	.73
H	271-360	299	184	181-240	209	65	.70
VH	361+	870	6016	241+	553+	2297	.66+
Average		844	6387		553	2426	.63+

Starting in September, 1968, all samples received by the North Dakota State University Soil Testing Laboratory are analyzed for $NaHCO_3$ extractable potassium. The benchmarks used by the North Dakota lab are: VL (0-50), L (51-120), M (121-210), H (211-300), VH (301+). These levels correlate closely with those used in Saskatchewan (Table 12).

Soil testing summaries have provided a great deal of information on the potassium status of Saskatchewan soils. Currently, soil test levels of potassium are available for approximately 30,000 fields in Saskatchewan. These data are on computer tape and can be summarized on the basis of location or soil type. The data in Table 13 show the levels of NH_4OAc potassium for the major soil zones in the province. It is interesting to note that exchangeable potassium decreases from the Brown Soil Zone to the Gray Soil Zone. Huang and co-workers have shown this difference in exchangeable potassium is apparently related to the nature of the potassium reserves (Table 14). The soils in the northern portion of the province contain a higher percent fraction of feldspar potassium relative to mica potassium. The release of potassium on extraction from potassium-feldspars is much less than from mica under usual soil pH conditions. These relationships help explain the differences obtained in levels of available potassium across the province.

Table 13. Relationship between NH_4OAc exchangeable potassium and Soil Zone in Saskatchewan 1967-1968

	NH_4OAc-K (lb/A)	
Soil Zone	Summerfallow	Stubble
Brown	963	1039
Dark Brown	960	994
Black	680	677
Thick Black	581	669
Grayish-Black	497	525
Gray	396	410

Table 14. Percent Fraction of Feldspar K in the Ap Horizons of Haverhill and Waitville Soils

Soil	NH_4OAc -K (lb/A)	Percent Fraction of Feldspar K $< 0.2\mu$	$0.2-2\mu$	$2-5\mu$	$5-20\mu$	$20-50\mu$	$50-500\mu$	% Total Potassium as Feldspars
Hv:L (Brown)	1139	0	3	31	51	63	60	40
Wv:L (Gray)	351	0	11	45	50	68	79	63

Huang and co-workers at the University of Saskatchewan have also been studying the reaction of hydronium ion with mica and feldspars with reference to release of potassium and the accompanying physico-chemical and structural changes.

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6.2 Micronutrients in Saskatchewan soils* (by J.W.B. Stewart)

Introduction

In this project started in 1966, the amount of background information on micronutrients in Saskatchewan soils was rather limited. There were reports of B deficiency in alfalfa and Cu deficiency in wheat, Mn deficiency (Grey Speck) had been noted in oats but there was a lot of conflicting information, especially in the northern regions of Saskatchewan on transition soils or on the Grey Wooded Soils. It was difficult to assess whether this was due to a macro- or micro-nutrient deficiency, as in many cases in the northern regions it could be due to a S or K deficiency.

The first approach, therefore, had to be a survey of the micro-nutrient status of the soils in the province. A question immediately raised was which plant or plants should be used? Secondly, which soil extractants should be used? Thirdly, how was it going to be possible to have a meaningful survey with the limited funds and manpower available, and fourthly, was there any means of tying this in with the routine soil survey that had classified most of the soils in the province?

The first question was answered when the costs of establishing test plots on the major soil associations in the province were calculated. Micro-nutrient deficiencies had been well documented for fruit trees and for vegetable crops, but the former were nearly non-existent and the establishment of vegetable trials throughout Saskatchewan would have been difficult. On the other hand, while there was only a limited amount of information on micronutrients in cereal crops, there were cereal

*A paper presented to the annual meeting of the Western Section of the National Soil Fertility Committee. Edmonton, Feb.13-14,1969.

variety trials throughout the province. These were carried out by the research personnel of the Canada Department of Agriculture and the Crop Science Department of the University.

In 1966, the guard rows of some variety trials were sampled on 26 plots; eight in the Brown, ten in the Dark Brown, four in the Black, and four in the Grey Wooded soil zones. The same variety of cereal was sampled at each site (Thatcher and Manitou wheat, Parkland and Betzes barley, and Russell and Gary oats).

Soil samples were taken at 0-6", 6-12", and 12-24". These soils were not only analyzed by extracting for micronutrients, but were also analyzed in the same way as a typical profile would be if taken by a soil survey team. This meant that on each soil we would know the pH, % total C, % organic C, conductivity, the mechanical analyses (% fine clay, % coarse clay, % silt, % coarse and % fine sand), available nutrients as assessed by the Saskatchewan Soil Testing Laboratory. The three extracting solutions that were chosen were an acid, a buffered weak acid and a chelating agent (0.1 N HCl, 1 N NH_4OAc at pH 4.8, and an EDTA - $(NH_4)_2CO_3$ solution).

It would appear from the data that it should be possible to relate the amount of Cu, Zn and Mn found in cereal crop to the soil properties. It further appears likely that the information provided by the Soil Survey can be used. Not all the analyses of typical soil profiles is presently on computer cards and unfortunately not all the samples have been taken in nice divisions like 0-6", 6-12" and 12-24".

Concurrent with the micronutrient survey, a second group of experiments was carried out. This was a cooperative study and involved quite a few members of the Department, notably - Messrs. Paul, Henry, Myers, Halm and Tahir. It could be given a broad heading, "The Effect of Organic Matter Additions to Soil on the Composition of Plants and the Yield and Quality of the Final Product". These experiments examined (1) the effect of levelling soils prior to irrigation on the yield and quality of tomatoes grown under irrigation and (2) the effect of incorporation of large amounts of straw on the yield and nutrient composition of wheat.

Other cooperative work was undertaken from experiments conducted from the Department of Horticulture at the University of Saskatchewan in 1967 and 1968. This involved the analysis of soil and foliar material from corn and potato experiments. In 1967, also, we added micronutrients to the fertilizer strip tests throughout the province.

This introduction gives some indication of the research of micronutrients in Saskatchewan and it is reported in detail in the following sections.

Experimental Work

Permission was obtained to take samples of two varieties of each of wheat, barley and oats at each cereal variety trial throughout Saskatchewan. At each site, care was taken to sample every tenth plant in the guard rows. In 1966, one sampling time was chosen (4-6 week stage) while in 1967 two sampling dates were used covering a longer growth period. Soil samples were taken at each site.

Results

During the intervening winter, the plant samples were analyzed and a variety of chemical extractants used to remove nutrients from the soil. The results of these plant analyses are shown in Tables 1 and 2. Table 1 gives the average composition of the dried plant material whereas Tables 2.1 to 2.3 divide this data up on an individual variety basis. Consideration of the data in Tables 2.1 to 2.3 shows that varietal differences are evident and that each variety should be considered by itself. The results of the soil extractants and total fusion analysis are given in Table 3. Table 3 presents average values for the total amounts of each element in the soil and, while it is unlikely that all of these elements would be available to the plant, the material is of interest on specific soils. Table 3 also presents the results and the amount of each element removed by three commonly used soil extractants. Other chemical characteristics were obtained on each soil: viz, CEC, mechanical analysis, available nutrients, pH, salt content (conductivity).

The results of all analyses were then statistically compared. The first step was to carry out a linear regression analysis ($y = A + Bx$) to compare the amount of an element in the plant dry matter versus the amount of the element extracted from the soil by a chemical treatment. This information was first obtained from a comparison of the 120 plant samples with the soil values and then obtained from a comparison of each species variety and the soil values. Elements in each species variety were also compared to soil chemical and physical characteristics such as pH, total clay %, fine clay %, coarse clay %, total C %, and organic C %.

Table 1. Average Composition of Cereals at 4-6 Week Growth Stage in Saskatchewan, 1966

(120 samples)

	Mean	Minimum	Maximum
Ca	0.2946% ± 0.1381	0.05%	0.7400%
Mg	0.2532% ± 0.0525	0.12%	0.39%
Mn	58.46 ± 18.51 ppm	21 ppm	109 ppm
Fe	139.98 ± 66.70 ppm	71 ppm	551 ppm
Cu	6.775 ± 3.80 ppm	1 ppm	18 ppm
Zn	26.017 ± 9.945 ppm	6 ppm	60 ppm

Remarks: Suspect contamination in Fe at values above 150 ppm

Table 2.1 MANITOU WHEAT - Average Composition of Dried Plant Material

		1966 4-6 Week	1967 5 Week	1967 7-8 Week
%	K	4.62 ± 1.16	3.15 ± 0.7	1.87 ± 0.53
	P	0.35 ± 0.066	0.27 ± 0.080	0.20 ± 0.053
	Ca	0.25 ± 0.099	0.34 ± 0.11	0.25 ± 0.064
	Mg	0.25 ± 0.050	0.21 ± 0.058	0.18 ± 0.45
ppm	Mn	58.3 ± 18.11	55.86 ± 15.46	48.0 ± 16.77
	Fe	152.1 ± 68.04	120.1 ± 48.82	83.8 ± 25.47
	B	3.05 ± 2.44	5.46 ± 1.41	5.86 ± 2.19
	Cu	7.45 ± 3.46	8.36 ± 1.79	7.32 ± 0.1
	Zn	27.0 ± 5.36	28.59 ± 9.19	21.59 ± 5.13
	Al	144.15 ±153.24	83.59 ± 51.71	58.09 ± 19.88
	Sn	10.8 ± 4.15	25.46 ± 5.70	19.46 ± 3.70
	Mo	2.01 ± 1.33	1.18 ± 0.50	0.86 ± 0.48
	Co	1.08 ± 0.67	2.07 ± 1.09	1.74 ± 0.95
%	Na	0.029± 0.019	0.04 ± 0.024	0.031± 0.023
	Si	0.34 ± 0.098	0.32 ± 0.097	0.22 ± 0.087
ppm	Ba	19.95 ± 5.35	20.0 ± 5.33	19.27 ± 3.89

Table 2.2 BETZES BARLEY - Average Composition of Dried Plant Material

		1966 4-6 Week	1967 4-6 Week	1967 7-8 Week
%	K	4.40 ± 1.10	2.98 ± 0.67	2.03 ± 0.83
	P	0.31 ± 0.070	0.27 ± 0.078	0.19 ± 0.051
	Ca	0.35 ± 0.16	0.45 ± 0.12	0.30 ± 0.10
	Mg	0.26 ± 0.053	0.24 ± 0.070	0.21 ± 0.049
ppm	Mn	54.3 ± 19.10	49.2 ± 12.53	34.14 ± 9.85
	Fe	123.4 ± 37.19	124.45 ± 50.35	80.3 ± 23.44
	B	4.55 ± 2.46	6.35 ± 2.37	6.43 ± 2.98
	Cu	7.65 ± 4.17	8.3 ± 1.72	7.29 ± 1.23
	Zn	27.95 ± 13.44	28.75 ± 12.06	22.4 ± 7.87
	Al	108.70 ± 99.72	72.10 ± 33.56	51.9 ± 16.35
	Sn	18.3 ± 12.43	29.75 ± 7.48	23.6 ± 5.83
	Mo	1.87 ± 1.01	1.24 ± 0.47	0.85 ± 0.41
	Co	0.98 ± 0.39	2.0 ± 0.88	1.57 ± 0.76
%	Na	0.12 ± 0.70	0.15 ± 0.058	0.15 ± 0.45
	Si	0.40 ± 0.18	0.43 ± 0.20	0.22 ± 0.11
ppm	Ba	12.75 ± 4.64	12.15 ± 4.80	10.10 ± 2.28

Table 2.3 GARY OATS - Average Composition of Dried Plant Material

		1966 4-6 Week	1967 4-6 Week	1967 7-8 Week
%	K	4.85 ± 1.09	3.68 ± 0.73	2.69 ± 0.70
	P	0.31 ± 0.071	0.25 ± 0.075	0.17 ± 0.50
	Ca	0.24 ± 0.082	0.34 ± 0.87	0.29 ± 0.83
	Mg	0.24 ± 0.041	0.22 ± 0.56	0.21 ± 0.55
ppm	Mn	60.05 ± 19.39	56.88 ± 16.70	51.67 ± 17.72
	Fe	119.05 ± 47.12	113.0 ± 46.22	82.25 ± 29.21
	B	5.09 ± 2.89	6.54 ± 1.44	6.83 ± 2.60
	Cu	4.77 ± 2.83	7.79 ± 1.72	6.96 ± 1.16
	Zn	21.77 ± 10.48	25.21 ± 7.58	19.50 ± 4.94
	Al	95.23 ± 94.63	56.08 ± 29.82	52.50 ± 35.55
	Sn	12.23 ± 7.46	23.92 ± 4.51	22.63 ± 4.64
	Mo	1.94 ± 1.10	1.22 ± 0.46	0.98 ± 0.46
	Co	1.31 ± 1.04	2.20 ± 1.09	1.67 ± 0.72
%	Na	0.095 ± 0.068	0.11 ± 0.65	0.13 ± 0.078
	Si	0.37 ± 0.16	0.52 ± 0.19	0.37 ± 0.20
ppm	Ba	5.96 ± 3.44	6.71 ± 1.46	7.38 ± 1.95

Table 3 Soil Analyses

		Total Fusion ppm	1N HCl Extraction	EDTA $(NH_4)CO_3$ solution	1N NH_4OAC (pH 4.8) ppm
		Mean	Mean	Mean	Mean
Ca	0-6"	12257 ± 4710	6685 ± 4071	313.4 ± 133.9	5940 ± 4364
	6-12"	16299 ± 9412	9481 ± 5852	503.8 ± 70.8	10351 ± 7671
	0-12"	28556 ±13276	16166 ± 9395	817.1 ± 175.0	16291 ±11506
Mg	0-6"	8117 ± 3225	1549 ± 809	224.5 ± 71.4	1032 ± 486
	6-12"	9521 ± 3486	1924 ± 924	249.1 ± 93.9	1734 ± 806
	0-12"	17639 ± 6545	3473 ± 1600	473.6 ± 136.9	2817 ± 1291
Mn	0-6"	549 ± 214	124.5 ± 30.2	22.2 ± 14.4	15.9 ± 8.1
	6-12"	456 ± 102	55.7 ± 21.7	4.6 ± 2.7	10.9 ± 11.0
	0-12"	1006 ± 250	176.9 ± 42.1	26.8 ± 16.7	25.9 ± 14.1
Fe	0-6"	23608 ± 7404	56.6 ± 28.4	12.7 ± 7.2	7.6 ± 2.7
	6-12"	25094 ± 6610	68.9 ± 52.6	6.9 ± 4.0	18.0 ± 5.4
	0-12"	48703 ±13519	125.5 ± 70.4	19.6 ± 11.0	25.1 ± 6.3
Cu	0-6"	87.7 ± 42.7	0.993 ± 0.567	2.69± 2.00	0.228 ± 0.167
	6-12"	76.0 ± 35.1	0.951 ± 0.830	2.44 ± 1.54	0.261 ± 0.181
	0-12"	163.6 ± 70.0	1.943 ± 1.24	5.13 ± 3.26	0.481 ± 0.318
Zn	0-6"	125.8 ± 31.0	4.106 ± 2.01	1.51 ± 1.19	0.78 ± 0.74
	6-12"	119.3 ± 46.8	1.519 ± 0.91	0.36 ± 0.27	0.66 ± 1.33
	0-12"	245.0 ± 64.8	5.625 ± 2.56	1.87 ± 1.28	1.44 ± 1.414

1. Relationship of the amount of an element in cereals to elements in chemical extractant.

The % Ca in the dry matter of the plant material was related to the % Mg and to the μg Zn/g in the plant material. It was not related to either the total Ca in the soil or to the amount removed by any of the three extracting agents. It was, however, positively related to the total amount of Zn and Cu in the soil, either in the 6-12" depth or in the 0-12" depth. The relationship with Cu and Zn will need further investigation, but is of little immediate use as a laboratory technique.

Plant Mg was found to be related to Ca, Mn, Cu and Zn in the plant and to these elements in the soil either to total elemental analysis values or to the amount of these elements removed by acid extractants. There was no significant relation between the amount removed by the chelating agent EDTA and the amount in the plant. Cu, Fe and Zn extracted by acid extractants gave negative correlation coefficients with plant Mg, while Mn and Ca showed positive correlation coefficients.

Plant Mn was found to be significantly related to 49 of the 77 other variables in the analysis. In 26 cases, the correlation coefficient was > 0.5 which for $N = 120$ represents an extremely high significance value. Plant Mn was positively related to the total amount of Fe, Ca and Mg in the 0-12" soil sample, and to the same elements and Mn in the 6-12" soil sample. The fact that total Mn in the 0-12" was not significantly correlated to the plant Mn must be a function of the chemistry of the 0-6" soil sample.

Acid extractants 0.1 N HCl and 1 N NH_4OAc gave similar types of results. Plant Mn gave positive correlation coefficients with Cu, Ca and Mg, and negative correlation coefficients with Zn and Fe with both extraction methods. EDTA - $(NH_4)_2CO_3$ gave slightly different results in that the amount of Ca removed was negatively correlated to the amount of Mn in the plant. Mn in the EDTA - $(NH_4)_2CO_3$ extract gave a negative correlation coefficient with Mn in the plant. This latter result, along with the difference in Ca results with acid and chelating extractants, provides an opportunity for further research on this subject.

In contrast to Mn, Cu and Zn, plant Fe was related to only a few of the 78 variables to which it was compared. At the outset, one might state that some of the values obtained for the plant material showed that there must have been some contamination of the plant material with soil. This would lead to extremely high Fe values in the plant material and would not aid in the comparison with soil extractants. The acid extractants showed that plant Fe was related to the Ca and Mg content of these extractants. But the chelating agent EDTA showed a negative correlation with the amount of Fe extracted and the amount in the plant. This is somewhat similar to the results obtained with Mn and one must assume that the relationship of Ca and Mg to Fe content must be considered.

While Cu was one of the hardest elements to determine in chemical extractants of the soil by atomic adsorption methods, because of the low amounts removed by roots and the concentration techniques required, it did prove to give the best correlation coefficients between the amount removed and the amount in the plant. Examination of the results showed that either the EDTA - $(NH_4)_2CO_3$ method which gives a correlation coefficient of 0.5505 for 120 samples or the NH_4OAc buffered to pH 4.8, which gives a correlation coefficient of 0.5732 for the same number of samples, could be used as a straight analytical method to predict the amount of Cu in the plant. Both these methods are recommended to the Soil Testing Laboratory for use with Saskatchewan soils.

The amount of Zn taken up by the plant material is related to the amounts of Ca and of Mg in the plant, but this is not surprising, due to the similarity of the cations, Ca, Mg and Zn. What is surprising is the fact that one gets a negative correlation coefficient between the amount of Zn in the plant and the total amount of Fe and the total amount of Mg in the soil. Of the two acid extractants used, HCl and NH_4OAc (pH 4.8), the former gave a highly significant correlation coefficient between the amount of Zn removed from the 0-6" soil samples and the amount of Zn in the plant, but did not give any relationship in the case of the 6-12" samples or with the combination of the two 0-12". One must assume then that the higher Ca content in the 6-12" level has confused the issue. A positive correlation was found between Zn extracted by EDTA in the 0-12" depth and the amount of Zn in the plant. With some reservation, this method could be used by the Soil Testing Laboratory, although further work is required on the relationship of Ca, Mg and Zn in the soil and the competitive effect of these cations on each other.

2. Relationship of the amount of an element extracted from the soil to other soil chemical and physical properties.

The next stage in this micronutrient study may be divided into two separate parts. The first part is an attempt to establish a relationship between the amounts of Mn, Fe, Zn and Cu removed from the soil by EDTA extraction, HCl extraction or NH_4OAc extraction and the normal chemical and physical properties that would be determined on samples taken on a routine soil survey. If this were possible, the different soil associations throughout Saskatchewan could be surveyed by applying a formula that included such things as pH, organic C, % fine clay, % total C or any other soil property that is normally measured in the soil survey laboratory.

The first step in this comparison was to run linear regression analyses between the amount of the element in the extractant and the soil properties. Analysis showed that the amount of Mn in the plant was related to the amount of Mn in the EDTA extractant, to the pH of the soil, and to the % fine clay in the soil.

Multiple regression analyses between all the soil properties and the amount of an element in the extracted solution are shown in Tables 4.1 - 4.4. A typical result would be that obtained for EDTA Mn in the 0-12" depth which may be predicted from the equation (143.21 - 16.5 pH + 5.1 % total C - 0.30 % fine clay). These three variables account for 67 percent of the variation and the probability of F shows that this equation is significant at the 0.1% level. A much better example would be the amount of Cu extracted by EDTA from the 0-12" depth and this could be predicted by the formula (1.84 + 0.2% fine clay - 4.44% organic C + 3.17% total C). This accounts for nearly 90% of the variation and the significance is at the 0.01% level.

It can be readily seen that the soils sampled in 1966 do show a relationship between soil properties and the amounts of Mn, Fe, Zn

Table 4.1 MANGANESE - Relationship of amount of manganese extracted from the soil to other soil properties.

		$r^2 \times 100$
EDTA Mn 0-6"	= 129.17-14.03 pH-0.29% Fine Clay	67.53
EDTA Mn 6-12"	= 26.24-3.40 pH + 2.57% Organic Carbon	67.65
EDTA Mn 0-12"	= 143.21-16.47 pH + 5.08% T.Carbon - 0.30% Fine Clay	67.37
HCl Mn 0-6"	= -94.93 + 95.35% Org. C - 1.39% Fine C + 32.59 pH - 81.59 T. Carbon	54.97
HCl Mn 6-12"	= -98.21 + 89.96% Org. C - 67.91% T.Carbon + 22.90 pH - 0.85% Fine Clay	67.98
HCl Mn 0-12"	= -163.62 + 162.67% Org. C - 135.85% T.Carbon + 51.26 pH - 1.88% Fine Clay	55.87
NH_4OAc Mn 0-6"	= 84.01 - 9.05 pH - 1.68% Org. C.	64.13
NH_4OAc Mn 6-12"	= best r2 x 100 equal to	26.34
NH_4OAc Mn 0-12"	= 72.08 - 6.25 pH - 0.10% Fine Clay	41.86

Table 4.2 IRON - Relationship of amount of iron extracted from the soil to other soil properties.

EDTA Fe 0-6"	= 59.19 - 5.82 pH - 0.24% Fine Clay	68.08
EDTA Fe 6-12"	= 24.57 - 0.16% Fine Clay - 1.85 pH	49.37
EDTA Fe 0-12"	= 92.41 - 8.89 pH - 0.36% Fine Clay	65.83
HCl Fe 0-6"	= best r^2 x 100 equal to	25.67
HCl Fe 6-12"	= 165.44 - 37.72% T.Carbon - 1.23% Fine Clay	50.17
HCl Fe 0-12"	= 412.48 - 2.02% Fine Clay - 33.73% T.Carbon - 23.16 pH	43.31
NH_4OAc Fe 0-6"	= 3.76 + 0.14% Fine Clay - 0.19 pH + 6.95% T. Carbon - 6.81% Org. Carbon	77.08
NH_4OAc Fe 6-12"	= 37.17 - 12.42% Org. Carbon + 6.72% Total C - 1.85 pH	44.81
NH_4OAc Fe 0-12"	= best r^2 x 100 equal to	27.32

Table 4.3 COPPER - Relationship of amount of copper extracted from the soil to other soil properties.

EDTA Cu 0-6"	= -3.23 + 0.11% Fine Clay - 0.39% Org. Carbon + 0.62 pH	79.46
EDTA Cu 6-12"	= 0.48 + 0.09% Fine Clay - 1.93% Org. Carbon + 1.25% Tot. Carbon	73.66
EDTA Cu 0-12"	= 1.84 + 0.20% Fine Clay - 4.44% Org. C + 3.17% Tot. C.	88.42
HCl Cu 0-6"	= best r^2 x 100 equal to	38.55
HCl Cu 6-12"	= best r^2 x 100 equal to	43.46
HCl Cu 0-12"	= 3.41 - 2.43% Tot. C + 1.97% Org. Carbon	41.02
NH_4OAc Cu 0-6"	= 0.14 + 0.01% Fine Clay - 0.057% Tot. Carbon	71.73
NH_4OAc Cu 6-12"	= -0.37 + 0.009% Fine Clay + 0.161% Tot.C - 0.256% Org. Carbon	81.15
NH_4OAc Cu 0-12"	= -1.04 + 0.016% Fine Clay - 0.184 pH - 0.105% Organic Carbon	84.43

Table 4.4 ZINC - Relationship of amount of zinc extracted from the soil to other soil properties.

		$r^2 \times 100$
EDTA Zn 0-6"	= 6.04 - 0.72 pH + 0.47% Org. C - 0.027% Fine Clay	79.08
EDTA Zn 6-12"	= 0.93 - 0.11 pH + 0.56% Org. C - 0.304% Tot.C	46.52
EDTA Zn 0-12"	= 8.64 - 1.05 pH + 0.74% Org. C - 0.026% Fine Clay	78.05
HCl Zn 0-6"	= 6.76 - 0.45 pH + 4.58% Org. C - 3.70% Tot.C - 0.048% Fine Clay	82.54
HCl Zn 6-12"	= 3.59 - 0.31 pH + 2.06% Org. C - 1.48% Tot.C	63.15
HCl Zn 0-12"	= 8.49 - 0.38 pH + 6.59% Org. C - 5.12% Tot.C - 0.066% Fine Clay	86.65
NH_4OAc Zn 0-6"	= best r^2 x 100 equal to	38.27
NH_4OAc Zn 6-12"	= best r^2 x 100 equal to	15.54
NH_4OAc Zn 0-12"	= best r^2 x 100 equal to	29.93

Table 5.1 Comparison of Manganese in Canthatch Wheat in ppm to the amount of soil extracts modified by soil physical and chemical properties.

(Variables tested: - % Fine Clay, pH, % Total Carbon, % Organic Carbon, HCl extracted Mn, EDTA extracted Mn and NH_4OAc extracted Mn. Values for these variables were obtained for the 0-6", 6-12" and 0-12" soil depths)

Soil Depth Samples			$r^2 \times 100$
0-6"	Plant Mn	= -23.50 + 0.665% Fine Clay + 9.29 pH	49.82
6-12"	Plant Mn	= -30.79 + 0.812% Fine Clay + 21.31 Tot.C - 22.70% Org. C	63.90
0-12"	Plant Mn	= -50.89 + 0.824% Fine Clay - 2.12 pH - 0.045 EDTA Mn - 34.34% Org. C + 32.01% Tot.C	64.02
0-6"	Plant Mn	= -23.50 + 0.665% Fine Clay + 9.29 pH	49.82
6-12"	Plant Mn	= 40.86 + 0.711% Fine Clay - 0.236 HCl Mn + 6.365% Organic Carbon	61.90
0-12"	Plant Mn	= 60.65 + 1.032% Fine Clay - 6.63 pH + 0.105 HCl Mn + 45.70% Tot.C - 51.05% Org. C	66.97
0-6"	Plant Mn	= 79.40 + 0.667% Fine Clay + 15.40 pH + 0.795 NH_4OAc Mn	53.77
6-12"	Plant Mn	= 12.22 + 0.989% Fine Clay + 25.16% Tot.C -30.62 % Org. C + 1.972 NH_4OAc Mn	73.81
0-12"	Plant Mn	= -72.96 + 0.685% Fine Clay + 13.815 pH + 0.558 NH_4OAc Mn	54.89

and Cu in some extracted solutions. EDTA appears to be the most consistent extractant, although HCl also gives high correlation coefficients. NH_4OAc was not successful with either Mn or Zn, but did show a good relationship with Fe and Cu. Results of this sort, however, are of no use unless the amount of the element in the extractant can be related to the amount in the plant. The next step was to try to use the amount of the element in the extraction solution, plus the soil properties, and develop an equation that would then predict the amount in the plant.

One further complication arose here as all the plant samples were not of the same species or variety. Preliminary analysis of the plants had shown that there was quite a difference in the amount of some of the micronutrients between varieties and between species. An example would be the amount of Cu in wheat and barley compared to that in oats in the 1966 year. It is, therefore, felt preferable to try to establish a relationship between the amount of the element in the same species and variety of the crop and the extraction solution in soil properties. This was again carried out with the aid of the computor center and the results are shown (Tables 5.1 to 5.5 inclusive).

Examination of these tables shows quite clearly that Mn, Zn and Cu may be predicted from an equation incorporating soil properties and with one extractant.

Conclusion

If the same type of results can be obtained for the 1967 crop, then the method can be used in the survey of micronutrients in Saskatchewan soils. There are, however, many other problems associated with this and the analysis of plants taken at two growth stages during

Table 5.2 Comparison of Copper in Canthatch Wheat in ppm to the amount in soil extracts modified by soil physical and chemical properties

Soil Depth Samples		$r^2 \times 100$
0-6"	Plant Cu = -9.28 + 0.471 EDTA Cu + 1.988 pH + 0.099 Fine Clay	64.95
6-12"	Plant Cu = 4.198 - 0.023 EDTA Cu + 0.024 pH + 0.188% Fine Clay - 6.805% Org. C + 4.954% Tot. C	68.99
0-12"	Plant Cu = 1.98 + 0.799 EDTA Cu + 0.187 pH + 3.769% Tot. C - 3.75% Org. C	70.28
0-6"	Plant Cu = 11.243 + 0.156% Fine Clay + 2.448 pH -1.304 HCl Cu	67.34
6-12"	Plant Cu = 6.063 + 0.176% Fine Clay - 0.954 HCl Cu -5.759% Org. C + 3.819% Tot. C	71.69
0-12"	Plant Cu = 7.138 + 0.179% Fine Clay - 0.024 pH - 0.769 HCl Cu - 5.955% Org. C + 4.612% Tot. C	75.49
0-6"	Plant Cu = 12.353 + 0.150% Fine Clay + 2.438 pH	63.4
6-12"	Plant Cu = 1.133 + 11.342 NH_4OAc Cu + 0.044% Fine Clay + 0.718 pH	59.18
0-12"	Plant Cu = -5.793 + 6.639 NH_4OAc Cu + 1.514 pH	60.81
0-12"	Plant Cu = 6.282 + 3.013 NH_4OAc - 0.385 pH + 0.131% Fine Clay + 6.097% Tot. C - 6.732 Org. C	72.60

Table 5.3 Comparison of Zinc in Parkland Barley to the amounts in soil extracts modified by soil physical and chemical characteristics

Soil Depth Samples		$r^2 \times 100$
0-6"	Plant Zn = 102.08 - 0.379% Fine Clay - 8.792 pH -3.288 EDTA Zn + 1.583% Org. C	58.79
6-12"	Plant Zn = 38.38 - 0.456% Fine Clay + 9.447 EDTA Zn	45.15
0-12"	Plant Zn = 75.842 - 0.367% Fine Clay + -5.144 pH	51.12
0-6"	Plant Zn = 115.739 - 0.391% Fine Clay - 9.180 pH - 3.903 HCl Zn + 23.757% Org. C - 20.940% Tot. C	67.74
6-12"	Plant Zn = 68.534 - 0.434% Fine Clay + 27.994% Org. C -3.126 pH - 6.142 HCl - 20.228% Tot. C	55.73
0-12"	Plant Zn = 107.62 - 0.485% Fine Clay - 6.709 pH - 4.245 HCl Zn + 41.855% Org. C - 34.669% Tot. C	67.52
0-6"	Plant Zn = 31.947 + 7.012 NH_4OAc Zn - 0.344% Fine Clay	63.84
6-12"	Plant Zn = 90.933 - 0.273% Fine Clay - 4.011 NH_4OAc Zn - 7.776 pH + 4.292% Org. C	68.72
0-12"	Plant Zn = 97.321 - 0.357% Fine Clay - 7.664 pH -2.426 NH_4OAc Zn	58.95

Table 5.4 Comparison of Zinc in Betzes Barley in ppm to the amount in soil extracts modified by soil physical and chemical characteristics

Soil Depth Samples		$r^2 \times 100$
0-6"	Plant Zn = 175.94 - 18.599 pH - 5.528 EDTA Zn -0.286% Fine Clay	69.91
6-12"	Plant Zn = 99.432 - 9.551 pH - 0.351% Fine Clay + 4.326% Tot. C + 6.976 EDTA Zn	59.87
0-12"	Plant Zn = 145.594 - 14.761 pH - 0.250% Fine Clay -2.195 EDTA Zn	61.11
0-6"	Plant Zn = 175.586 - 17.258 pH + 0.661% Tot. C -3.849 HCl Zn - 0.408% Fine Clay	72.34
6-12"	Plant Zn = 108.43 - 10.575 pH - 0.360% Fine Clay + 5.205% Tot. C	58.27
0-12"	Plant Zn = 161.831 - 14.376 pH - 0.490% Fine Clay -4.195 HCl Zn + 23.287% Org. C - 17.399% Tot. C	67.43
0-6"	Plant Zn = 140.424 - 15.137 pH - 3.045% Tot. C + 3.918 NH_4OAc	68.24
6-12"	Plant Zn = 144.033 - 15.434 pH - 3.277 NH_4OAc Zn	58.55
0-12"	Plant Zn = 132.243 - 13.273 pH - 0.226% Fine Clay -1.387 NH_4OAc Zn	60.84

Table 5.5 Comparison of Copper in Russell Oats in ppm to the amounts in the soil extracts modified by soil physical and chemical characteristics

Soil Depth Samples		$r^2 \times 100$
0-6"	Plant Cu = -22.515 + 3.317 pH + 0.043% Fine Clay + 8.694% Org. C - 7.703% Tot. C + 0.571 EDTA Cu	65.39
6-12"	Plant Cu = -4.310 + 1.212 pH + 0.304% Fine Clay -2.597 EDTA Cu + 9.545% Tot.C - 12.568% Org. C	62.56
0-12"	Plant Cu = -14.944 + 2.542 pH + 0.058% Fine Clay	51.37
0-6"	Plant Cu = -24.184 + 3.658 pH + 0.083% Fine Clay + 7.371% Org. C - 6,517% Tot:C	62.87
6-12"	Plant Cu = -9.814 + 2.157 pH - 1.235 HCl Cu	51.04
0-12"	Plant Cu = -14.94 + 2.542 pH + 0.058% Fine Clay	51.57
0-6"	Plant Cu = -24.184 + 3.658 pH + 0.083% Fine Clay + 7.371% Org. C - 6.517% Tot. C	62.87
6-12"	Plant Cu = -9.93 + 1.786 pH + 6.657 NH_4OAc Cu	47.62
0-12"	Plant Cu = -14.94 + 2.542 pH + 0.058% Fine Clay	51.57

the following season only serves to highlight the difficulty. Many questions remain to be answered and one of these might be, "What is the effect of soil water tension on the nutrient uptake of share crop on identical soils?" Another might be, "What is the effect of incorporation of stubble or organic matter on the composition of plants and yield and quality of the final product?" A third factor might be, "How does the composition of the dried plant material alter during the growing season?" We know for instance that the plant requires N and P at different times during the growth stage. A great demand in P is, of course, during the first 8 weeks of growth when it picks up 75% of its total P while N is required at a slightly later date. Are we then in fact correct in assuming that the growth stage that we sample at is the right one? These are some of the questions that we have still to answer.

6.3 Plant uptake and immobilization of ^{15}N-labelled ammonium nitrate in a field experiment with wheat* (by R.J.K. Myers and E.A. Paul)

ABSTRACT

Uptake and recovery of ^{15}N-labelled NH_4NO_3, applied to wheat in two Dark Brown Chernozemic soils, were determined in the presence and absence of incorporated straw in a two-year field experiment. Yield and nitrogen uptake of both soil and fertilizer N were unaffected by rate of nitrogen applications or by straw addition, but differed between soils and between years.

Significant quantities of applied N were immobilized, immobilization being greater in the coarser-textured Bradwell soil, in the presence of straw, and at the higher rate of N. The quantity of immobilized N declined by 20 to 30 per cent in the second year. Most N was immobilized in the plough layer (0 to 15 cm), but significant immobilization occurred in lower horizons. Addition of 4480 kg N/ha of straw caused 13 kg N/ha additional immobilization from 112 kg N/ha fertilizer in both soils.

Recovery of applied N was 64 to 66 per cent in the coarse-textured soil and 75 to 84 per cent in the clay soil. Neither rate of fertilizer nor straw addition significantly influenced recovery. The losses were attributed to denitrification and possibly leaching.

Only 11 per cent of added straw-N was taken up by two successive crops. Total recovery was approximately 90 per cent.

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The results indicated that the yield depressions due to added straw found in greenhouse studies are unlikely under field conditions in Chernozemic soils where residue decomposition is relatively slow and the nitrogen-supplying power is high.

INTRODUCTION

Nitrogen fertilizer application is becoming increasingly important for cereal production in dryland agriculture. Efficient use of these large quantities of fertilizer requires a knowledge of its patterns of uptake, movement and transformations, as they affect the fertilized and subsequent crops.

While the magnitude of response of cereal crops to nitrogenous fertilizer in Chernozemic soils is well-tabulated (14), the underlying reactions of the fertilizer under field conditions are not as well known. The results from growth chamber and greenhouse studies utilizing ^{15}N have generally indicated that recovery of fertilizer nitrogen ranges from 70-100% with an average of 85%. Additions of straw usually results in higher recoveries both in cropped and uncropped soils (1,18).

The immobilization (or reversion) of fertilizer nitrogen in soil has been found to be influenced by the presence of an energy source affecting microbial growth (18) and the possibility of non-biological interaction of ammonia with the soil constituents (9). The reverse process, that of a stimulation of soil nitrogen availability by the presence of added fertilizer, also has been demonstrated. It is known that mineralization-immobilization reactions proceed simultaneously, and that one measures essentially the net differences between the two reactions (18). Since only 1-3% of the nitrogen immobilized can be accounted for by the roots of the crop, the contribution of available carbon by the plant for immobilization by the soil microorganisms must be considered.

Zamyatina, et al (29) utilizing a split root technique, have indicated that the increased availability of soil nitrogen, attributable to fertilizer nitrogen, was affected by the physiological metabolism of the fertilized plants and the associated microflora, plus an interaction between the soil and fertilizer. However, there was usually little N interchange apart from the plant root system.

Field studies with ^{15}N have been conducted on small grains and maize (2, 11, 12, 15, 17, 21, 25), rice (27, 28), sugar cane (22, 23, 24) and grasses (3, 10). Investigations of the balance of ^{15}N and the release of mineral-N in forest soils also have been reported (4, 19).

The type of field experiments have varied from small rod-row plots through microplots, lysimeters and the fertilization of individual plants. One of the most significant contributions has been that of Carter, et al (10) who designed an experiment to obtain a balance sheet under field conditions. Microplots consisting of the soil mass inside cylinders 30 or 60 cm in diameter were seeded to Sudan grass or left uncropped. Recovery of added ^{15}N ranged between 96-102% in an initial experiment, but dropped as low as 77% after 10 months. The losses were attributed to gaseous losses, since special precautions were taken to restrict leaching. An important conclusion from this work was the fact that core sampling was not suitable for determination of soil ^{15}N values. It was found necessary to remove the whole soil mass from within the cylinder, in layers, and to sub-sample after thorough mixing of each layer.

The results from growth chambers and greenhouse studies plus field studies, not using tracers, have generally been confirmed by the few field experiments conducted to date, and it should not be necessary to conduct a large number of ^{15}N field experiments. There are, however, some instances in which only field studies can yield the required answers. This includes studies relative to the availability of different sources of nitrogen, where the efficiency of rate, time and position of placement relative to root exploitation and natural structure must be considered. Growth chamber and greenhouse studies cannot be directly applied to field conditions where the relative rate of various processes such as immobilization and mineralization may be different under field conditions. The straw residue problem exemplifies this principle. While the laboratory data warn of the dangers of yield depression due to immobilization of added N by decomposing straw residues (8), no evidence for such an effect on wheat yields has been found in the field under dryland farming conditions in the Canadian prairies (13).

By using microplots and low levels of enrichment, the problem of cost and fertilizer dilution in an unknown soil volume can be overcome. This paper describes a field experiment using ^{15}N labelled fertilizer applied to wheat at two sites in Chernozemic soils. Uptake of applied N over two seasons and recovery of residual N in the soil were determined. These data were compared to laboratory investigations using similar soils.

MATERIALS AND METHODS

Materials

The experiment was conducted near Saskatoon on two cultivated Dark Brown Chernozemic soils: a neutral soil of very fine sandy loam surface texture (Bradwell Association), and a slightly alkaline soil of clay surface texture (Sutherland Association). When the experiment was initiated in May 1967, the soils contained 24 and 70 kg NO_3-N/ha (0 to 60 cm), respectively. The Bradwell site had been a brome-grass pasture, and the Sutherland site had grown wheat in the previous year. The sites were 3 kilometers apart.

Ammonium nitrate, doubly labelled with ^{15}N (6.504 ^{15}N% abundance), was applied as a solid and mixed with the 0 to 2.5 cm layer of soil.

Unlabelled wheat straw containing 0.65 per cent N and labelled oat straw containing 1.07 per cent N (0.5141 ^{15}N% abundance), were used in certain treatments. Both materials were chopped into 2.5 cm lengths before application.

Field Techniques

The procedures followed were similar to those of Carter et al (10). The experiment was conducted in the field. The treatments were applied to microplots made by imbedding 31 cm, diameter steel cylinders into the soil to a depth of 91.5 cm, so that 5 cm remained above the soil surface. The cylinders were installed on a 4 metre grid using a powered hammer. Little compaction or obvious soil disturbance resulted. The following procedure was followed. The plough layer (0 to 15 cm) was removed from each cylinder and was replaced by an equivalent quantity of thoroughly mixed soil from an adjacent area to ensure uniformity.

of the surface soil of all microplots. In the straw treatments, the straw was mixed with the 0 to 10 cm soil layer; the N fertilizer was mixed with 0 to 2.5 cm soil, and the wheat was sown (22 seeds per cylinder) at 2.5 cm depth. The area surrounding the cylinders also was sown to wheat to provide a buffer area. The 1968 crop was seeded in the same way, but no additional N fertilizer was applied.

At sowing 1967, 2.5 cm water was added to all cylinders and, owing to moisture stress conditions, 2.5 cm water was applied to all cylinders twice during July, 1967.

Experimental Treatments, Harvesting and Soil Sampling

Labelled ammonium nitrate was applied to Bradwell soil at 56 and 112 kg N/ha with and without unlabelled straw at 4480 kg/ha. In a further treatment, labelled oat straw was applied at 4480 kg/ha without N fertilizer. Labelled ammonium nitrate was applied to Sutherland soil at 112 kg N/ha with and without unlabelled straw at 4480 kg/ha. All treatments were replicated three times.

Successive wheat crops were grown in 1967 and 1968. The mature wheat plants were removed at ground level, and were separated into straw and grain by hand. At harvest, 1967, and at sowing, 1968, the 0 to 7.5 cm soil was removed, mixed and a small representative soil sample taken.

After the 1968 harvest, the cylinders were removed and transported to the laboratory, where the soil was quantitatively removed in layers (0 to 7.5, 7.5 to 15, 15 to 30.5, 30.5 to 61, 61 to 91 cm), air dried, weighed, thoroughly mixed and subsampled for analysis.

Root material was removed from soil samples by dry sieving and hand picking. After root removal, a subsample of soil was ground to 100 mesh. Grain, straw and root material were dried, weighed and ground in a mill using a 1-mm screen.

Methods of Analysis

Total nitrogen was determined on all soil, root and straw samples by Kjeldahl digestion with salicylic acid modification, to include nitrate, and on grain samples by the standard Kjeldahl digestion (5). The ammonia was distilled into 2 per cent boric acid and titrated electrometrically. After acidification with 0.3 ml N H_2SO_4, the distillate (containing at least 2 mg N) was concentrated under vacuum to 2 ml.

Isotope-ratio analysis was performed on a M.A.T. GD 150 mass spectrometer using a double inlet, double collector technique. Nitrogen was released by reaction with alkaline hypobromite in a Rittenburg tube (6).

Soil mineral nitrogen was extracted with 2 M KCl, and NH_4^+-N and NO_3^+-N and NO_3^--N were determined by the double distillation procedure (5). To obtain sufficient N for isotope-ratio analysis, 2 mg non-enriched NH_4^+-N was added to the soil nitrogen obtained upon distillation analyses. After concentration to 2 ml, the isotope-ratio analysis was carried out as described above, and the true enrichment calculated by correcting for the added non-enriched N.

Throughout the analyses, precautions were taken to avoid errors in analysis caused by contamination (7).

Calculation of ^{15}N Content and N Recovery

^{15}N% abundance was calculated by standard methods. The enrichment of the sample was found by subtracting the natural % abundance of the material (determined separately for plant material and for all sample depths in both soils) from that of the individual sample. The recovery of excess ^{15}N in a sample was then calculated from the total N contents and enrichment values, using the measured total weight of the soil or plant sample. The results are expressed mostly as kg N/ha. While the conversion of microplot data to these units could be questioned, it does provide a good basis for comparison.

Yield data were in all cases the most variable component of the analytical sequence, while isotope-ratio analyses were of high precision.

RESULTS

Yield

There were no significant yield effects between the two rates of fertilizer or of straw addition. However, the Sutherland soil out-yielded Bradwell approximately threefold and twofold in 1967 and 1968, respectively (data not reported). Yields in 1968 were approximately 50 and 10 per cent greater than in 1967 in Bradwell and Sutherland soils, respectively. Lack of treatment effects are attributed to the relatively high rates of N chosen and to the droughty conditions in the Bradwell soil. The growing season precipitation in 1967 was 15.6 cm, of which one-third was received in August, too late to influence growth or yield. The effect of the below average rainfall was more evident on the coarser textured Bradwell soil. There was a non-significant trend towards yield depression by the straw treatments in Bradwell in 1967. This trend seemed to be reversed in 1968, when the growing season precipitation was 27.9 cm.

Nitrogen Uptake

There was a trend towards a depression of fertilizer N and soil N uptake by straw at the coarse textured site in the first year; however, the reverse trend occurred in the second year (Table 1). Fertilizer N uptake was greater on clay soil than on sandy loam, probably due to more favorable moisture conditions. Total recovery in plant material (which does not include a root sampling in 1967) was about 25 per cent of the applied fertilizer N for the coarse textured and about 50 per cent for the clay soil. Grain protein tended to be higher at the higher rate of fertilizer, but was not affected by straw addition. Root N was determined only in the second crop where it accounted for an average of 14 per cent of the total labelled plant N in that crop.

Uptake of straw N was relatively small, i.e. 11.2 per cent of added straw N in the two crops. In the first year, 5.8 per cent was removed in plant tops; in the second year, 3.5 per cent. Jansson (16) estimated that the N in plant residues had a half-life of 20 years; these results do not dispute this.

Nitrogen Immobilization

Significant quantities of fertilizer N were immobilized (Table 2). The peak of immobilization probably occurred some time between sowing and harvest of the first crop (9), so the August 1967 figures for immobilized N are not considered to be maximum figures. A more intensive sampling program would be required to assess maximum immobilization. The August figures do reflect the quantity of added N unavailable to the first crop.

Immobilization was higher in the coarse than in fine textured soil with straw markedly increasing immobilization. Immobilized N declined with time, the 20 to 30 per cent decline between August, 1967 and August, 1968 indicating remineralization. The decline in labelled organic-N between August 1967 and May 1968 was enhanced by the mild autumn and spring conditions--soil temperatures remained above freezing throughout September and October 1967 and again during March and April 1968. Most of the immobilization occurred at lower depths. By extrapolating the 0 to 7.5 cm results, we estimated the N immobilized in the 0 to 15 cm soil layer at the end of the first growing season (Table 3). From this we calculated the effect of straw on immobilization in the plough layer. This calculation used the figures for labelled soil organic-N for 0 to 15 cm from August 1968 and assumed that the remineralization rates for 0 to 7.5 and 7.5 to 15 cm soil were similar. The 4480 kg/ha straw treatment increased immobilization by 13.5 kg N/ha in the 112 kg N/ha treatment in both soils. The fact that 20 to 40 kg N/ha were immobilized provides one explanation as to why applied N recoveries in field experiments rarely exceed 50 per cent.

Nitrogen Balance

The data were used to draw up a nitrogen balance sheet (Table 4). From 64.4 to 83.8 per cent of the added N was recovered, indicating losses of 16 to 36 per cent. In the coarse-textured Bradwell soil, neither rate of fertilizer, nor straw addition affected the percentage recovery of added N. In the Sutherland clay soil, recovery was higher, especially the straw-treated plots. The high losses were associated with reasonably high concentrations of ^{15}N in the lower depths. This indicates that the possibility of leaching beyond 91 cm cannot definitely be discounted. A very wet period occurred just prior to the final sampling. However, at this time, the soil was wet only to 76 cm. If there was no leaching, then the 16 to 36 cm per cent loss must have been caused by ammonia volatilization and/or denitrification.

A nitrogen balance for ^{15}N-labelled mineral-N applied to soils similar to those used in the field studies, was conducted in the growth chamber (Table 5). The losses ranged from 1-8% in the loam soil and 4-17% in the clay, with the highest losses occurring in the soils receiving the greatest moisture stress treatment, i.e. those that dried out the most before re-watering. Appreciable loss only occurred in the treatments still containing nitrate-nitrogen at the end of the experiment. This indicated that the availability of nitrate-nitrogen for denitrification process was the greatest factor influencing the loss, since in this case no leaching occurred and denitrification was actually inversely correlated with soil moisture availability during the growth period (20).

DISCUSSION

The use of steel cylinders to form experimental microplots has many advantages. It restricts the mobile forms of N to vertical movement--lateral movement of N out of the experimental area is prevented; water erosion is prevented and wind erosion is minimized. The cylinders allow the test plants to absorb N only from the experimental area, and prevent robbing of tagged fertilizer by outside plants. That is, well-controlled conditions are provided while the definition of a field experiment is not violated.

The possible dangers are that water infiltration may tend to be concentrated down the walls of the cylinder, particularly in a cracking clay soil such as Sutherland. Soil temperatures may also be affected by heat being conducted into the soil by the steel cylinder--this effect is small in view of the volume of soil contained within the cylinder. The danger must exist, in some soils, of compaction of the soil during cylinder installation. As lateral water movement is prevented, results obtained would need careful interpretation when such movement is a natural phenomenon in a particular soil.

The results for yield (not reported) showed that there was no significant effect of straw addition. We thus agree with Ferguson (13) who found that continued straw application for eight years did not reduce wheat and oats yields. Ferguson considered that cereal straw applied repeatedly had a residual positive effect on yield because it eventually increased the amount of available N.

These field results contradict greenhouse experiments which demonstrate considerable yield depression and large amounts of N immobilized by decomposing straw (8). Our results would suggest reasons for this discrepancy. In the first place, yields measured in field experiments are variable and small yield depressions either are not detected or are too small for significance. Secondly, the decomposition of straw under field conditions seems to be slower than under controlled greenhouse conditions. In greenhouse experiments, plant residues have often been applied as finely ground material, and frequently these residues have been applied at rates exceeding those expected in the field. Greenhouse conditions of controlled adequate moisture and favorable temperatures are rarely encountered in the field.

In our field experiment, the relatively cool soil temperatures in May (12°C at 10 cm) and the dry surface soil conditions could have delayed maximum immobilization so that plant uptake process had a temporary advantage. In any case, the 112 kg N/ha rate of N fertilizer was high enough to allow an excess of available N, so that plant uptake and immobilization processes should have been able to proceed without hinderance.

The unamended soil was capable of immobilizing considerable quantities of applied N. The effect of straw applied at a level somewhat higher than average for this area was to increase immobilization by only 13.5 kg N/ha (or 12 per cent of the added N). The depression in yield that could be expected from immobilization of 13.5 kg N/ha would then be of the order of 140 to 200 kg/ha (or 2 to 3 bu/ac), a depression that could not be reliably detected in a field experiment.

That a rapid initial remineralization of part of the immobilization N took place is demonstrated. This effect has been well demonstrated in greenhouse experiments (26), which also show a progressive stabilization of the N not remineralized (8). After two growing seasons, it might be expected that the immobilized N remaining would have achieved relative stability.

The nitrogen balance sheet for the field study showed recoveries that fell within the expected range (1). In this experiment, natural rainfall conditions prevailed. It thus differed from a recent report of a similar study (10) in which rainfall accession was limited to prevent leaching. Undoubtedly some N was lost by physical mechanisms such as wind erosion, removal of plant material by hail and wind storms, and by rodents and birds. Care was taken to minimize wind erosion losses, but losses due to animals may have occurred, and damage was caused by a hailstorm before the harvest of 1967. But, even if 25 per cent of the Bradwell plant material was lost in this way, it would account for only 3 to 5 per cent of applied N. The usual figure for ammonia volatilization for N mixed with the soil is 5 to 10 per cent. The major other sources are denitrification and leaching. Only one treatment showed considerable amounts of N at depth after the wet period prior to soil sampling. Since the soil at the lowest depth of the cylinder was not moist at this time, the only other possibility for leaching was during the previous fall and spring. Therefore, denitrification probably was the major source of N loss.

The field and laboratory data presented in this paper corroborate other laboratory experiments in relation to the nitrogen balance of soil and the turnover rate of mineral-N. The field data, however, differ from many pot experiments, in that the addition of fertilizer-N did not significantly increase the contribution of soil nitrogen. Similar results* have been obtained in a larger field experiment which also did not indicate a significant increase in the release of soil organic nitrogen, during the growth period, attributable to added fertilizer.

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*Private communication, J.L. Henry, University of Saskatchewan, Saskatoon.

Table 1. Plant uptake of soil and fertilizer N by wheat in a field experiment

Treatment*	Grain plus straw				Roots	
	1967		1968		1968	Total
	Soil N	Fert.N	Soil N	Fert.N	Fert.N	Fert.N
	kg N/ha					
Bradwell						
56	18.1	13.9b†	33.5	2.0c	0.6	16.5
56 + S	12.7	9.3b	38.6	1.9c	0.6	11.8
112	13.5	16.4b	32.1	7.0b	1.4	24.8
112 + S	9.6	11.8	45.1	10.1a	1.3	23.2
Sutherland						
112	45.8	44.4a	83.9	10.6a	1.2	56.2
112 + S	44.5	51.6a	67.0	5.4b	1.0	58.0
Bradwell						
^{15}N straw‡	11.1	2.6	31.8	1.6	1.0	5.2

*56 and 112 kg N/ha as labelled NH_4NO_3; + S treatments received 4480 kg straw/ha.

†Values followed by the same letter are not significantly different at the 5 per cent level.

‡Containing 46 kg N/ha.

Table 2. Labelled fertilizer N retained in surface soil (0 to 7.5 cm) at various sampling dates in two field soils

Treatment†	Sampling date*					
	August '67		May '68		August '68	
	Organic	Mineral	Organic	Mineral	Organic	Mineral
	kg N/ha					
Bradwell						
56	11.1c§	1.3	9.0c	0.3	7.4c	0.1
56 + S	16.9b	0.9	16.4b	0.4	13.0b	0.1
112	16.4b	4.4	15.4b	0.8	13.2b	0.3
112 + S	27.1a	3.6	25.6a	0.8	20.3a	0.4
Sutherland						
112	11.8c	4.6	7.7d	1.6	7.8c	0.2
112 + S	19.6b	7.6	13.8b	1.7	14.5b	0.3
Bradwell						
^{15}N-Straw‡	26.3	1.5	27.4	1.3	18.6	0.4

*Date of application May, 1967

†56 and 112 kg N/ha as labelled NH_4NO_3; + S treatments received 4480 kg/ha straw.

‡Containing 46 kg N/ha.

§Values in any one column followed by same letter are not significantly different at the 5 per cent level.

Table 3. Estimated immobilization of labelled fertilizer N in the plough layer (0 to 15 cm) under field conditions

Soil	Rate of Fertilizer	Fertilizer N in soil organic matter		
		- Straw	+ Straw	Difference
	kg N/ha			
Bradwell	56	17.4	24.1	6.7
	112	25.6	39.1	13.5
Sutherland	112	22.6	36.1	13.5

Table 4. Nitrogen distribution and balance sheet from field experiment using ^{15}N-labelled materials

Soil	Treatment*	^{15}N recovered					
		Plant material	0-15 cm	15-30.5 cm	30.5-61 cm	61-91 cm	Total
	kg N/ha	%	%	%	%	%	%
Bradwell	56	29.4	21.8	7.8	3.0	3.0	65.0a†
	56 + S	21.0	34.4	5.8	2.4	1.0	64.6a
	112	22.1	19.2	7.1	5.3	12.4	66.2a
	112 + S	20.7	27.7	5.4	4.2	7.2	65.3a
Sutherland	112	50.2	14.2	6.4	3.3	0.7	74.8ab
	112 + S	52.0	25.0	4.1	2.1	0.6	83.8b
Bradwell	^{15}N-straw‡	11.3	79.1	n.d.	n.d.	n.d.	90.4

*56 and 112 kg N/ha as labelled NH_4NO_3; S(straw) treatments received 4480 kg/ha straw.

†Values followed by same letter are not significantly different at the 5 per cent level.

‡Containing 46 kg N/ha.

Table 5. Nitrogen balance for ^{15}N labelled mineral N applied to Oxbow loam and Melfort clay under three moisture stress treatments in the growth chamber

		^{15}N recovery			
Soil	Moisture Treatment	Plant	Soil Org. N	Soil Min-N	Total
		mg N/pot			
Oxbow (L)	Low stress	142	56	0	198
	Med. stress	138	42	18	198
	High stress	118	30	38	184
Melfort(C)	Low stress	120	72	0	192
	Med. stress	136	40	10	186
	High stress	126	30	10	166

Amount applied = 200 mg/pot

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